

SPD-718-01

INLET VELOCITY DISTRIBUTION OF A FULL SCALE FLUSH INLET WATERJET

AD A032261

**DAVID W. TAYLOR NAVAL SHIP
RESEARCH AND DEVELOPMENT CENTER**

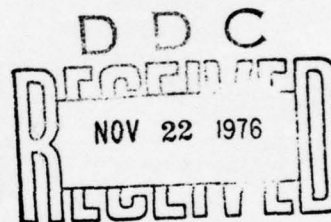
Bethesda, Md. 20084



INLET VELOCITY DISTRIBUTION OF A
FULL SCALE FLUSH INLET WATERJET

by

Reuel S. Alder



B

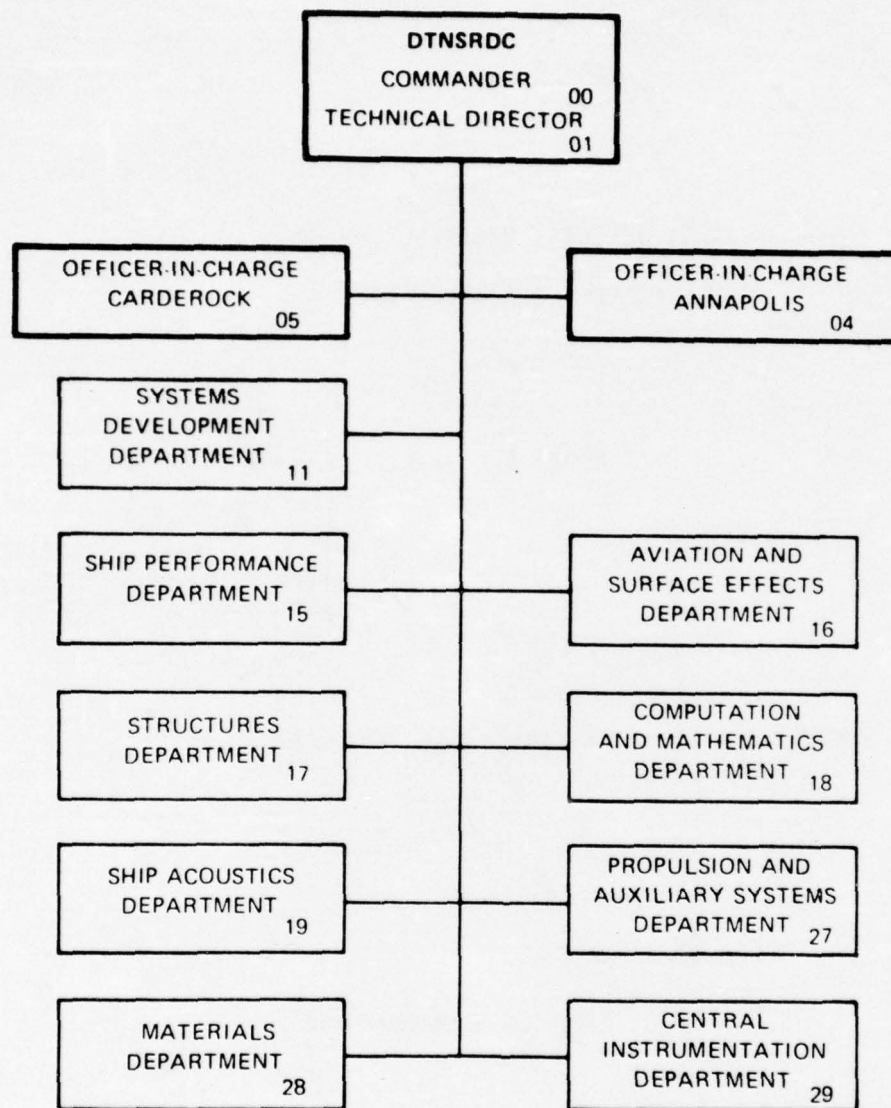
APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

SHIP PERFORMANCE DEPARTMENT

August 1976

SPD-718-01

MAJOR DTNSRDC ORGANIZATIONAL COMPONENTS



UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER SPD-718-01	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Inlet Velocity Distribution of a Full Scale Flush Inlet Waterjet		5. TYPE OF REPORT & PERIOD COVERED
7. AUTHOR(s) Reuel S. Alder		6. PERFORMING ORG. REPORT NUMBER
9. PERFORMING ORGANIZATION NAME AND ADDRESS David W. Taylor Naval Ship R&D Center Bethesda, Maryland 20084		8. CONTRACT OR GRANT NUMBER(s) F61412
11. CONTROLLING OFFICE NAME AND ADDRESS		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Program Element 62756N Task Area ZF 61 412 001 Work Unit 1532-021
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		12. REPORT DATE August 1976
		13. NUMBER OF PAGES 84
		15. SECURITY CLASS. (of this report) ZF61412001
16. DISTRIBUTION STATEMENT (of this Report) APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Waterjets Flush Inlet Waterjets Internal Flow Measurement		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Full scale experiments at sea were conducted to evaluate the performance of two waterjet impellers and to determine the velocity distribution in the inlet of a typical waterjet. Inlet velocity and nozzle velocity measurements were made concurrently with full scale performance evaluation of a waterjet powered planing craft. Two impellers were evaluated in the experiments; one stock impeller, standard with the waterjet and one newly designed and constructed at the David W. Taylor Naval Ship Research and		

DD FORM 1 JAN 73 1473

EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

20.

Development Center (DTNSRDC). Evaluation of both impellers was conducted for bollard and underway conditions.

Velocity distributions for the underway conditions varied from zero velocity at the top of the duct to approximately 175% of craft velocity at the bottom of the duct. Bollard conditions were markedly different with the highest flow velocity occurring at the center of the duct.

Experimental results indicate a need to improve the inlet design before potential improvement can be made in impeller design. The inlet performance could be improved by lengthening and smoothing out the duct or by redirecting the inlet flow with the use of vanes. Results of the impeller evaluations have been reported under separate cover.

ACCESSION for	
NTIS	White Section <input checked="" type="checkbox"/>
DOC	Bull Section <input type="checkbox"/>
UNANNOUNCED	<input type="checkbox"/>
JUSTIFICATION	
BY	
DISTRIBUTION/AVAILABILITY CODES	
Dist.	AVAIL. OR/OF SPECIAL
A	

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

TABLE OF CONTENTS

	Page
ABSTRACT	1
ADMINISTRATIVE INFORMATION	2
INTRODUCTION	2
DESCRIPTION OF APPARATUS	4
EXPERIMENTAL PROCEDURE	5
CALIBRATION	5
TEST PROCEDURES	8
DATA ACQUISITION AND ANALYSIS	8
RESULTS AND DISCUSSION	10
CONCLUSIONS	13
REFERENCES	15

LIST OF FIGURES

	Page
Figure 1 - Waterjet Pump Profile.....	16
Figure 2 - Cross Section of Duct in the Plane of the Traversing Probes	17
Figure 3 - Waterjet Inlet	18
Figure 4 - Pressure Probes	19
Figure 5 - Pressure Probes as Seen by the Impeller	20
Figure 6 - Pressure Probes as Evaluated in the Towing Basin	20
Figure 7 - Calibration Curves for Semi-Conductor Probe	21
Figure 8 - Pressure Probe Response While Moving in Water	22
Figure 9 - Velocity Distribution Across Duct for Underway Experiments with Standard Impeller and 5.75" (0.146 m) Nozzle	23
Figure 10 - Velocity Distribution in Duct for Underway Experiments, Special Runs with Standard Impeller and 5.75" (0.146 m) Nozzle	24
Figure 11 - Velocity Distribution in Duct for Bollard Experiments with Standard Impeller and 5.75" (0.146 m) Nozzle	25
Figure 12 - Velocity Distribution in Duct for Underway Experiments with DTNSRDC Impeller and 5.75" (0.146 m) Nozzle	26
Figure 13 - Velocity Distribution in Duct for Underway Experiments, Special Runs with DTNSRDC Impeller and 5.75" (0.146 m) Nozzle	27
Figure 14 - Velocity Distribution in Duct for Bollard Experiments with DTNSRDC Impeller and 5.75" (0.146 m) Nozzle	28
Figure 15 - Velocity Distribution in Duct for Underway Experiments with DTNSRDC Impeller and 6.00" (0.152 m) Nozzle	29
Figure 16 - Velocity Distribution in Duct for Underway Experiments, Special Runs with DTNSRDC Impeller and 6.00" (0.152 m) Nozzle	30

LIST OF FIGURES

	Page
Figure 17 - Velocity Distribution in Duct for Bollard Experiments with DTNSRDC Impeller and 6.00" (0.152 m) Nozzle	31
Figure 18 - Velocity Distribution at Nozzle Exit	32
Figure 19 - Static Pressure Distribution in Duct for Underway Experiments with Standard Impeller	33
Figure 20 - Static Pressure Distribution in Duct for Bollard Experiments with Standard Impeller	34

LIST OF TABLES

TABLE 1 - TEST CRAFT	35
TABLE 2 - WATERJET STANDARD IMPELLER.....	35
TABLE 3 - DTNSRDC NEW DESIGN IMPELLER	35
TABLE 4 - OUTLINE OF EXPERIMENTAL DATA	36
TABLE 5 - UNDERWAY EXPERIMENTS WITH STANDARD IMPELLER AND 5.75 IN. (0.146 m) NOZZLE	39
TABLE 6 - UNDERWAY EXPERIMENTS, SPECIAL RUNS WITH STANDARD IMPELLER AND 5.75 IN. (0.146 m) NOZZLE	48
TABLE 7 - BOLLARD EXPERIMENTS WITH STANDARD IMPELLER AND 5.75 IN. (0.146 m) NOZZLE	50
TABLE 8 - UNDERWAY EXPERIMENTS WITH DTNSRDC IMPELLER AND 5.75 IN. (0.146 m) NOZZLE	53
TABLE 9 - UNDERWAY EXPERIMENTS, SPECIAL RUNS WITH DTNSRDC IMPELLER AND 5.75 IN. (0.146 m) NOZZLE	60
TABLE 10 - BOLLARD EXPERIMENTS WITH DTNSRDC IMPELLER AND 5.75 IN. (0.146 m) NOZZLE	62
TABLE 11 - UNDERWAY EXPERIMENTS WITH DTNSRDC IMPELLER AND 6.00 IN. (0.1524 m) NOZZLE	65
TABLE 12 - UNDERWAY EXPERIMENTS, SPECIAL RUNS WITH DTNSRDC IMPELLER AND 6.00 IN. (0.1524 m) NOZZLE	74
TABLE 13 - BOLLARD EXPERIMENTS WITH DTNSRDC IMPELLER AND 6.00 IN. (0.1524 m) NOZZLE	75

NOTATION

A_D	Developed blade area	ft ² , m ²
A_E	Expanded blade area	ft ² , m ²
A_O	Impeller disc area $\pi D^2/4$	ft ² , m ²
c	Chord length	ft, m
D	Impeller maximum diameter	ft, m
f_M	Blade section camber	ft, m
g	Acceleration due to gravity	ft/sec ² , m/s ²
P	Impeller pitch	ft, m
p_{atm}	Atmospheric pressure	psia, Pa
p_d	Dynamic pressure, $p_d = p_t - p_s$	psia, Pa
p_s	Local static pressure	psia, Pa
p_t	Local total pressure, $p_t = p_s + 1/2\rho V_i^2$	psia, Pa
r	Local radius	ft, m
R	Nozzle radius or impeller maximum radius	ft, m
t	Maximum blade section thickness	ft, m
V_C	Velocity of carriage	ft/sec, m/s
V_i	Local upstream velocity	ft/sec, m/s
V_j	Average nozzle velocity	ft/sec, m/s
V_p	Velocity computed from pressure probe measurements	ft/sec, m/s
V_s	Boat velocity	knots
x	r/R	
Z	Number of blades of a propeller	
α	Inflow angle to probe	degrees
ρ	Density of fluid	lbf-sec ² /ft ⁴ , Kg/m ³

ABSTRACT

Full scale experiments at sea were conducted to evaluate the performance of two waterjet impellers and to determine the velocity distribution in the inlet of a typical waterjet. Inlet velocity and nozzle velocity measurements were made concurrently with full scale performance evaluation of a waterjet powered planing craft. Two impellers were evaluated in the experiments; one stock impeller, standard with the waterjet and one newly designed and constructed at the David W. Taylor Naval Ship Research and Development Center (DTNSRDC). Evaluation of both impellers was conducted for bollard and underway conditions.

Velocity distributions for the underway conditions varied from zero velocity at the top of the duct to approximately 175% of craft velocity at the bottom of the duct. Bollard conditions were markedly different with the highest flow velocity occurring at the center of the duct.

Experimental results indicate a need to improve the inlet design before potential improvement can be made in impeller design. The inlet performance could be improved by lengthening and smoothing out the duct or by redirecting the inlet flow with the use of vanes. Results of the impeller evaluations have been reported under separate cover.

ADMINISTRATIVE INFORMATION

This work was carried out under Independent Exploratory Development (IED) program funding. Project identification was Program Element 62756N, Task Area ZF 61 412 001, Work Unit 1532-021.

INTRODUCTION

Waterjet propulsion systems have application where appendage and draft restrictions are critical to maneuverability and overall craft performance. A limitation of waterjet application is their lower efficiency when compared to marine screw propellers¹. Reduced efficiency in waterjet systems may come from inlet, duct, impeller, stator, and nozzle losses and from losses due to raising the water from an inlet level to the level of the exit nozzle.

This IED program was initiated to determine the potential for increasing waterjet efficiency by improvement of impeller design technology. Specifically, the task was to determine whether or not marine propeller design procedures could be used to design and consequently improve the efficiency of a waterjet impeller. The tools to be considered were lifting line and lifting surface propeller design procedures which have reached a high degree of sophistication in recent years. For marine propellers, these procedures allow design for given thrust production or horsepower absorption at desired shaft

¹ Brandau, J. H., "Performance of Waterjet Propulsion Systems - A Review of the State-of-the-Art," Journal of Hydronautics, Vol. 2, No. 2, pp. 61-76 (April 1968).

revolution rate and with a minimum of cavitation. Since marine propellers are axial flow devices, an obvious candidate for impeller design improvement would be an axial flow (preferably single stage) waterjet.

In the initial stages of the program it was apparent that two major requirements were 1) a vehicle and/or a set of operating conditions for which to design and 2) a mechanism on which the product (presumably a waterjet impeller) could be experimentally evaluated. The only craft which met both of these requirements and which was available within the desired time frame was a 31-ft (9.45 m) 12,600 lb (69,392 N) planing craft maintained by the Naval Ship Engineering Center, Norfolk Division (NAVSECNORDIV). The craft is equipped with two flush inlet waterjets. The waterjet is a single stage (one impeller and one set of stator vanes) waterjet unit with near axial flow through the impeller plane. Craft availability along with acceptable waterjet internal geometry led to its selection to fulfill requirements (1) and (2) above.

A secondary requirement in utilizing marine propeller design procedures is an accurate description of inflow into the propeller (impeller) plane. No adequate information of this type was available for the waterjet (or any other candidate axial-flow waterjet). Therefore, the experimental program described in this report was undertaken primarily to supply that inflow information.

DESCRIPTION OF APPARATUS

Experiments were conducted using a 31-ft planing craft described in Table 1 and propelled by two typical waterjets. The waterjets are single stage mixed flow pumps powered by separate diesel engines rated at 216 hp each at 2800 rpm. Two impellers, one of standard design and one of new design, were provided for the starboard waterjet along with two nozzles of different diameter that were interchanged during the experiments. Instrumentation was included on the starboard waterjet to measure torque, rpm, and internal pressures. The port waterjet operated in its normal configuration. A description of the standard waterjet dimensions and ducting profile is found in Figure 1. The cutting plane AA shown in Figure 1 was the location of two traversing pressure probes designed to measure static and total head pressure. Cross section AA is described in more detail in Figure 2 and the 11 positions at which the upstream pressure measurements were made are designated. The waterjet inlet and grating has been defined in Figure 3.

Two separate impellers as described in Tables 2 and 3 were evaluated in the starboard waterjet. Table 2 describes the standard waterjet impeller and Table 3 is a description of the DTNSRDC impeller designed for the waterjet using propeller design procedures. Two separate nozzles were used during the experiments, the standard 5.75 in. (0.146 m) diameter nozzle and a 6.0 in. (0.1524 m) diameter nozzle.

The two upstream probes were traversed vertically across the duct while another probe traversed the exit nozzle horizontally. A detailed description of these probes is given in Figures 4, 5, and 6. Figure 4 gives the dimensions of the probes. Figure 5 is a photograph of the probes mounted to the traversing mechanism and installed to the waterjet access port through which the probes operated. Figure 6 shows a close view of the probes mounted on a strut/foil arrangement used in the open water velocity calibration of the transducers.

The pressure probes were strain-gaged diaphragm type. The two upstream probes were equipped to measure static, as well as total head pressure. The total head pressure probe has a diaphragm recessed about 3/16 in. (4.76 mm) in a counter bore. The static pressure probe was mounted 1 1/2 in. (38.1 mm) behind and in line with the total head probe. The nozzle probe was designed for measuring only total head pressure.

Two traversing probes were used in the upstream measurements to insure that a single transducer failure would not lead to lost test time. The probes did differ in construction; one probe had a foil-type gaged diaphragm, the other probe (starboard) had a semi-conductor gaged diaphragm. The semi-conductor probe had a higher sensitivity and better signal resolution than the "foil" probe.

EXPERIMENTAL PROCEDURE

CALIBRATION

Three separate calibrations of the pressure probes were carried out; one pre-test static calibration and two post-test calibrations.

The pre-test calibration was performed using a dead weight tester for pressures from 5 to 15 psig. Most of the test data, however, was below atmospheric pressure and a recalibration using a vacuum chamber verified the calibration constants. The static calibration results are presented in Figure 7.

The static calibrations provided a means of estimating the error in the pressure measurements. A least square regression analysis was made on the calibration data and a standard deviation was computed. From this analysis the error band on the pressure data was found to be $\pm .1$ psi (.69 kPa). The pressure error can be related to the velocity error by examining the equation used to calculate velocity. From Bernoulli's equation,

$$p_d = p_t - p_s = (1/2)\rho V_i^2$$

differentiating and solving for dV_i ,

$$dV_i = d(p_d)/\rho V_i$$

The term $d(p_d)$ has a value equal to the sum of the errors in the p_t and p_s measurement or $\pm .2$ psi (1.38 kPa). The error in velocity measurement or the dV_i term is approximately ± 3.0 ft/sec (0.91 m/sec) at a velocity of 5.0 ft/sec and ± 0.3 ft/sec (0.091 m/sec) at a velocity of 50 ft/sec (15.24 m/sec). This error analysis assumes that Bernoulli's equation applies and that the probes are not subject to systematic errors in measuring p_t and p_s .

Dynamic calibrations of the probes were conducted with towing carriage tests in the DTNSRDC - Langley Tank No. 1 over a speed range of 15 - 30 ft/sec (4.57 - 9.14 m/sec). It was impractical to conduct a dynamic calibration of the pressure probes below 15 ft/sec (4.572 m/sec) because carriage speed fluctuations and the small output of the transducers produced data of questionable accuracy in this speed range. At speeds above 30 ft/sec (9.144 m/sec), high steady and unsteady forces were produced by the (surface-piercing) probes; therefore calibrations planned in this range were not carried out in order to protect the probes.

The probes were towed in the basin with the probe shafts penetrating the free surface. In order to prevent the shafts from ventilating to the atmosphere and destroying the static pressure reading, the probes were mounted through a flat plate as shown in Figure 6. During calibration, the plate was submerged approximately one inch. The results shown in Figure 8 indicated that the total head pressure was relatively insensitive to the angle at which flow impinges upon the probe. With the probe turned at an angle of 35 deg, there was only a small difference in the output when compared with the output at 0 deg. The static pressure gage was found to be sensitive to both the magnitude and direction of the flow approaching the pressure probe.

Combining the results of the static and dynamic calibrations, it is estimated that the error in the velocity reading is within 15% of reading over the range of 10 to 50 ft/sec (3.05 to 15.24 m/sec).

TEST PROCEDURES

Experiments as summarized in Table 4 were conducted under six separate conditions. There were two impellers and two nozzles available for the tests. The standard impeller was used with the standard 5.75 in. diameter (0.0146 m) nozzle while the DTNSRDC impeller was used with the 5.75 in. nozzle and 6.00 in. (0.0152 m) nozzle. The three resulting groups were further broken down into a bollard test and an underway test. Bollard tests were conducted with the boat tied to the dock. Underway tests were conducted in open water on a previously layed out course of 4107 feet running on a line 30 deg Southeast. During the underway tests the boat traversed the course twice, once in each direction at the same pump rpm settings. At the end of each set of underway runs, special conditions were set up by running the starboard engine at a lower rpm than the port engine. All tests were conducted under the same approximate sea conditions.

DATA ACQUISITION AND ANALYSIS

Due to a limited space aboard the test craft, data were recorded on a Honeywell 5600C Analog Tape Recorder and played back to a shore-based computer after testing. Prior to being recorded the data signals were conditioned using Model 4470 Endevco signal conditioners and Dana amplifiers. Data were analyzed using an Interdata Model 70 mini-computer with 32K memory. Interfaced with the computer was an Analogic 5800 14-bit analog to digital converter. Included in the system was a high speed printer, ASR-33 teletype and a Kennedy Model 3110 9-track digital tape deck.

Nine data channels were recorded; time code signal, single pulse, multi-pulse, negative-positive probe position signal, and five pressure signals. Magnetic pickups generated the single and multi-pulse signals by sensing the single tooth and 90-tooth gears attached to the propeller shaft. These signals used in conjunction with the computer will enable the analysis of periodic signals synchronized with shaft revolutions.

During testing, initial data zeroes were collected for all channels with the starboard engine off and the port engine idling. Data were collected continuously throughout a run making it necessary to provide a marker on tape indicating when the traversing probes were in position. This was accomplished by the use of a switching box which could be triggered to either a positive or negative voltage. The switch was triggered positive for approximately ten seconds after setting the position of the probes.

The analog data were played back to the computer system, digitized at a rate of 100 samples per second, and stored on magnetic tape using a continuous data collection package developed at DTNSRDC. Data averaging and further analysis was accomplished using both the Interdata mini-computer and a CDC 6600. In the analysis, it was assumed that Bernoulli's equation applies and that $V_i = \sqrt{(p_t - p_s) 2/g}$. For the nozzle velocity computation the static pressure was assumed to be atmospheric pressure.

RESULTS AND DISCUSSION

Waterjet flow velocity (pressure) data were collected over a variety of craft operating conditions and these have been summarized in Table 4. During each run there were 11 probe positions at which the pressure data were collected for approximately 10 seconds. The results of this data collection and averaging are tabulated in Tables 5 through 13, with each table representing a group of runs with a specific pump configuration and test procedure. The tables are separated into eight columns of data. The first three columns correspond to the measured static pressure, measured total pressure and computed velocity for each of the 11 positions of the port probe. Position one corresponds to the uppermost measuring position in the duct. The next three columns are the same quantities for the starboard probe. The next column is an average of port and starboard velocities (starboard velocity when port probe inoperative) and the last column is the nozzle probe measurement of localized jet velocity.

The nozzle probe was not reliable and failed completely at the end of the first set of tests. Therefore, the nozzle data were accurate only for runs 20 - 28. Figure 18 depicts the nozzle velocity profile along a horizontal line passing through the centerline of the pump at 1.75 in. axial clearance from the nozzle.

The average of the port and starboard velocities as reported in Tables 5 - 13 are presented in graphical form in Figures 9 - 17.

The graphs are grouped in the same manner as the tables. Underway tests have only half of the data taken presented in graphical form because the tests were duplicated for each rpm condition. Duplicate runs agreed too closely for presentation on the same graph. There was also good agreement between measurements made with the starboard probe and the port probe. Static pressures, total pressures, and velocities were in close agreement with the exception of a few early runs in which the port static pressure probe was inoperable.

Figure 9 is typical of the duct velocity profile measured with the boat underway. The velocity determined at the bottom of the duct is at least twice that determined at the top. This ratio is consistent for all rpm conditions below 2400 rpm with a gradual increase in all velocities across the duct as the rpm is increased. At rotational speeds of 2400 rpm or above, the upper half of the duct begins to become choked off until at 2700 rpm there is very little flow through the upper part of the duct. The 2400 rpm condition corresponds to the point at which the boat begins to plane and experience abrupt changes in speed and trim angle. Figure 12 displays the same trends for the DTNSRDC impeller.

Data shown in Figure 10 indicate that craft velocity and trim angle determine the velocity profile in the duct. Presented in this graph are three runs in which the starboard rpm is constant and the port rpm is varied to change craft speed and trim. The faster the boat travels the more distorted the velocity profile becomes. Figures 13 and 16 are similar graphs for the DTNSRDC impeller.

From an examination of Figures 9 - 17 it is apparent that the nonuniform inlet velocity is a large source of energy loss. One possible improvement to the nonuniformity would be to add adjustable turning vanes across the inlet. This would redistribute the flow and improve pump performance. Another solution might be to lengthen and smooth the inlet to allow a more gradual inflow into the impeller. Figures 9 - 17 also indicate that inlet velocities are unaffected by the impeller geometry. Figure 9 was generated from tests using the standard impeller while Figure 12 was the same type of test using the DTNSRDC impeller. The nonuniform velocity distribution was present in both tests and relatively unchanged by a change of impeller. Because of the severity of the inflow nonuniformity it would appear impractical to use the velocity data obtained in these tests in the generation of a new impeller design.

Figures 11, 14, and 17 are graphs of the velocity profiles determined during bollard tests. When the boat is held stationary the velocity profiles in the duct are the reverse of those determined during underway tests. The upper portion of the duct has the highest flow velocities.

The static pressure profile as measured by the starboard probe in the standard pump configuration is shown in Figures 19 and 20. It is apparent in these graphs that the static pressure is always greatest at the top of the duct and lowest at the bottom of the duct for both bollard and underway tests. However, the reason for

this static pressure distribution is not the same for both tests. For the bollard tests the static pressure decreases from the top of the duct to the bottom of the duct corresponding with an increase in fluid velocity to just below the centerline of the pump. However, the lower probe positions appear to be in a region of separated flow with both the static pressure and fluid velocity being small. The low static pressure in the bottom of the duct for underway tests is a result of high fluid velocities in that region. It would appear that the flush inlet operated as more of a ram inlet at the higher boat speeds with most of the water entering straight into the impeller plane at the bottom of the duct.

CONCLUSIONS

1. Velocity (pressure) measurements were successfully conducted on a full scale craft in the inlet of a typical waterjet, thus eliminating any scaling problems or other compromises associated with waterjet/hull simulation.

2. Probe measurements indicated a large variation in the velocity distribution for bollard condition tests versus underway tests. The inlet geometry or lack of smooth contour created regions of relatively large velocities. The duct velocity for the bollard tests was greatest at the duct center and smallest at the bottom of the inlet while underway tests indicated velocities greatest at the bottom and smallest at the top of the duct.

3. At rpm values of 2400 or more, for the underway conditions, the upper half of the duct appeared to be a region of separated flow with the waterjet flush inlet becoming more of a ram inlet. Under these conditions most of the inflow entered through the lower half of the duct.

4. From experiments in which the starboard engine or test pump was maintained at a constant rpm and the craft speed was varied by changing the port engine rpm, it was determined that the inlet velocity distribution was greatly influenced by the craft velocity and trim angle.

5. Improvements could be made in pump performance by changing inlet conditions. An easy way to accomplish this would be to add vanes across the inlet to turn and redistribute the flow entering the duct in order that a smoother inlet condition could be achieved.

6. Inlet flow conditions were not affected by impeller geometry. Similar tests with two different impellers produced essentially the same inlet inflow velocity distributions.

7. One of the overall objectives of this IED program had been to determine the applicability of marine propeller design procedures in designing axial flow waterjet impellers. The specific objective of the current experiments was to determine the inflow conditions for which the impeller is to be designed. It was determined, however, that the flow distribution in the inlet of the typical waterjet (on this test craft and at the craft speeds evaluated herein) is too severe to consider in impeller design techniques.

8. Evaluation of the impeller/nozzle systems and recommendations regarding future experimentation and overall program continuation are included in a subsequent report.

REFERENCES

1. Brandau, J. H., "Performance of Waterjet Propulsion Systems - A Review of the State-of-the-Art," Journal of Hydronautics, Vol. 2, No. 2, pp. 61-76 (April 1968).

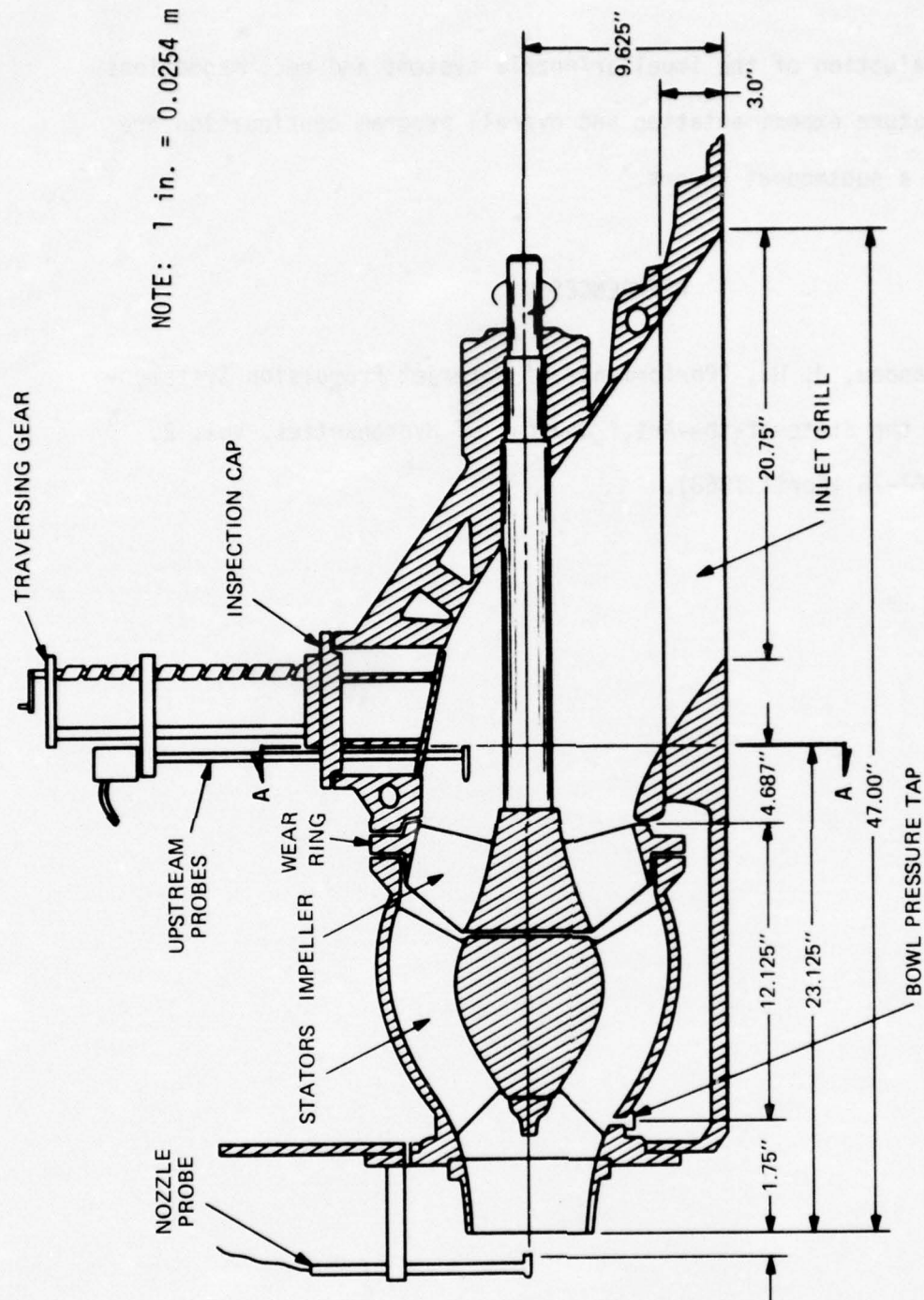
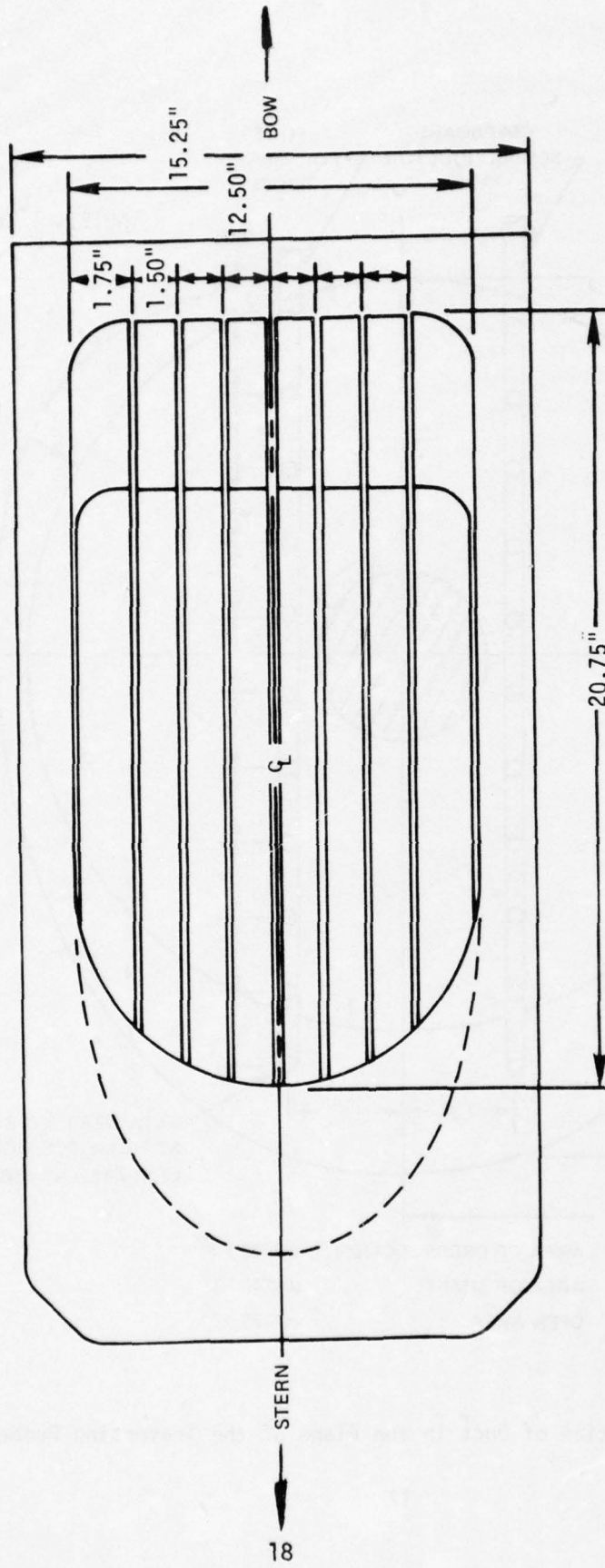


Figure 1 - Waterjet Pump Profile



NOTE: 1 in. = 0.0254 m

Figure 3 - Waterjet Inlet

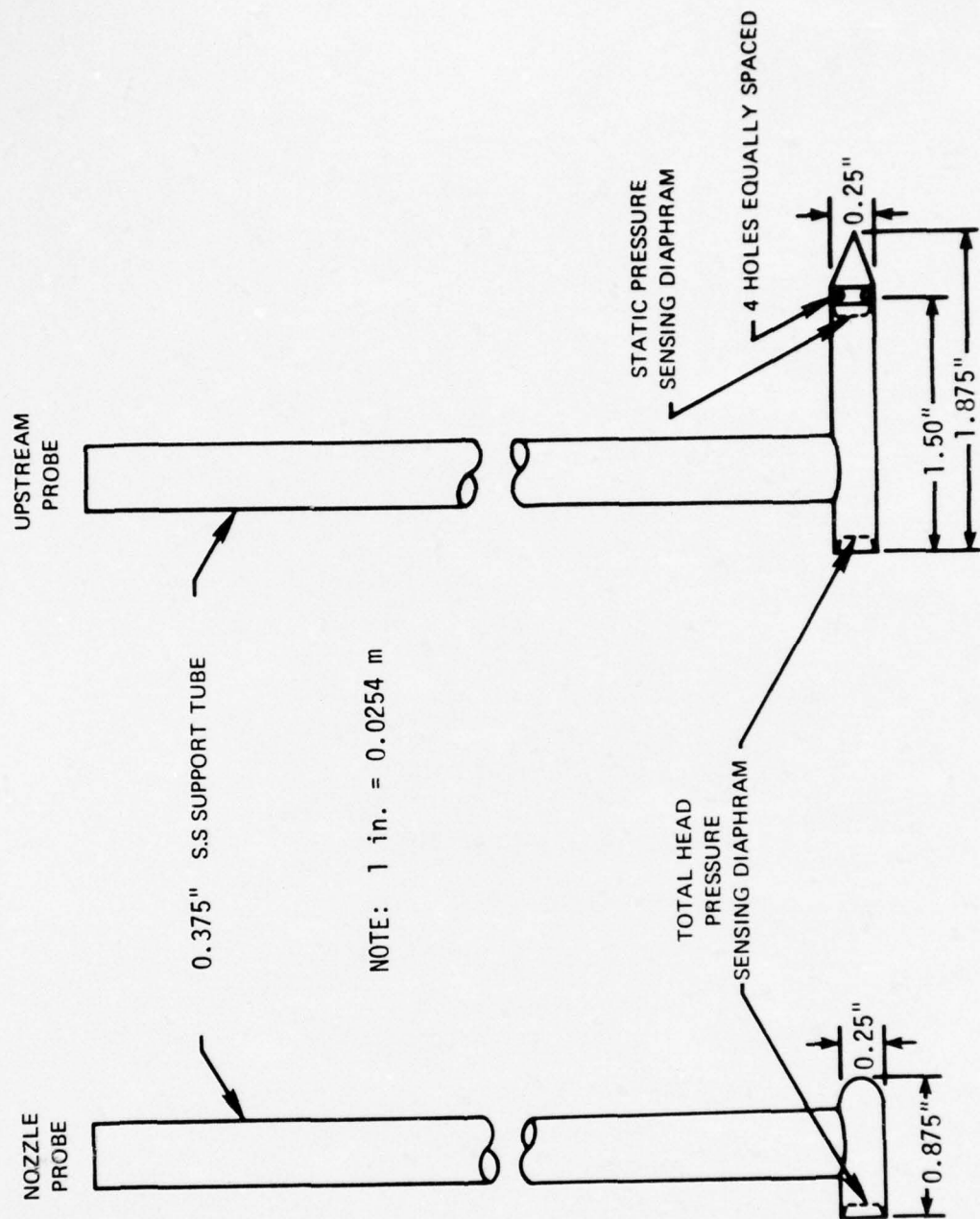


Figure 4 - Pressure Probes

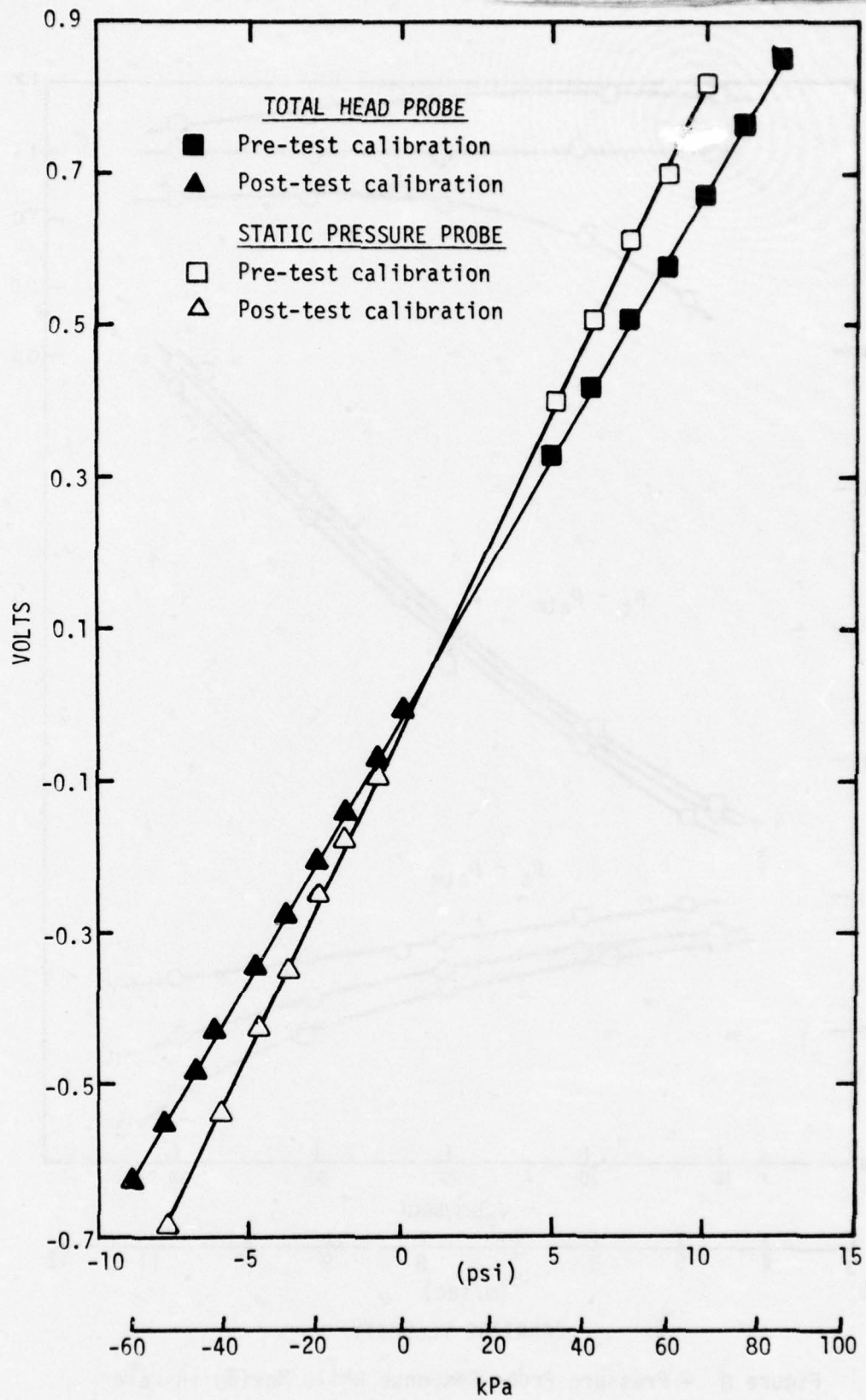


Figure 7 - Calibration Curves for Semi-Conductor Probe

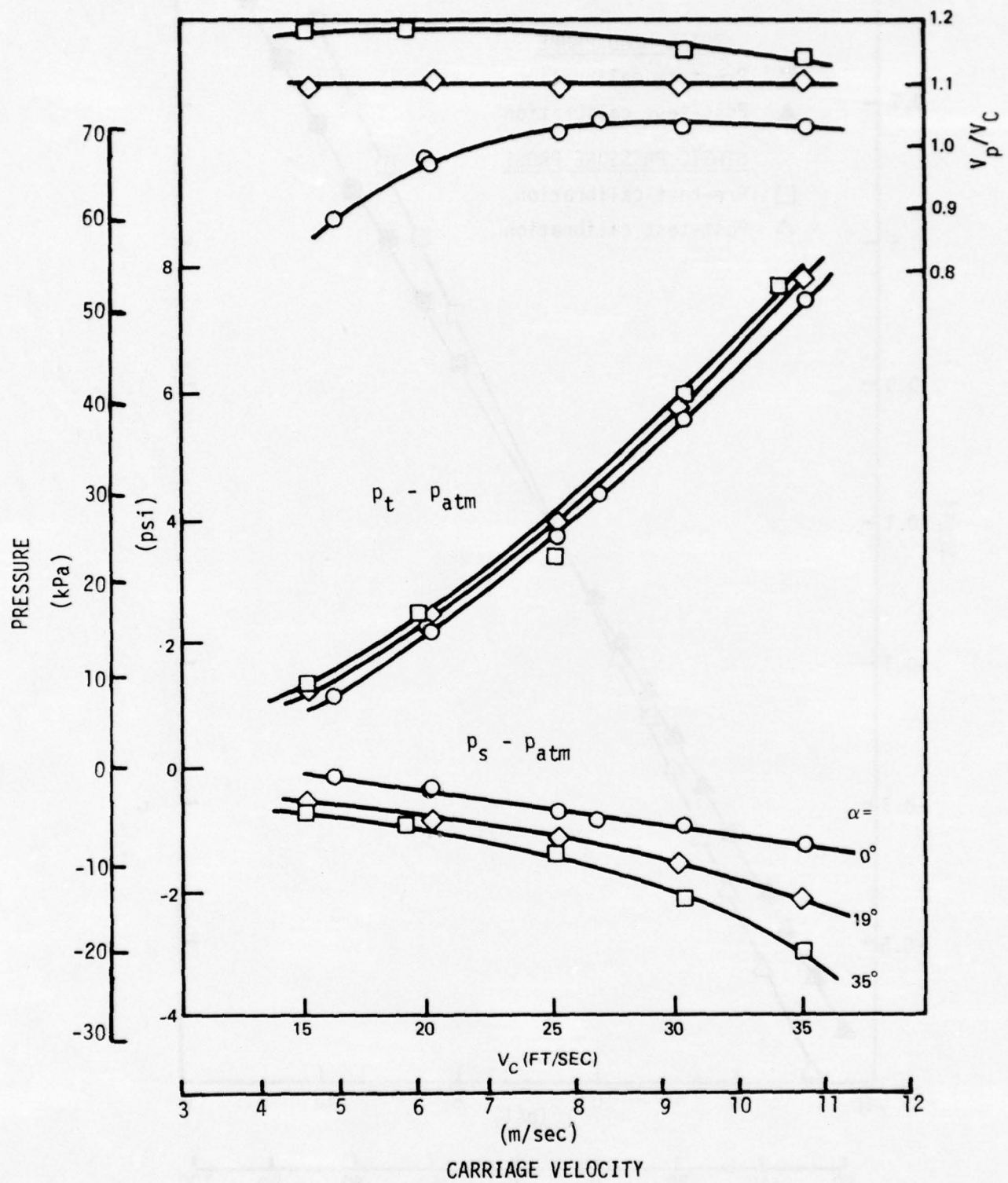


Figure 8 - Pressure Probe Response While Moving in Water

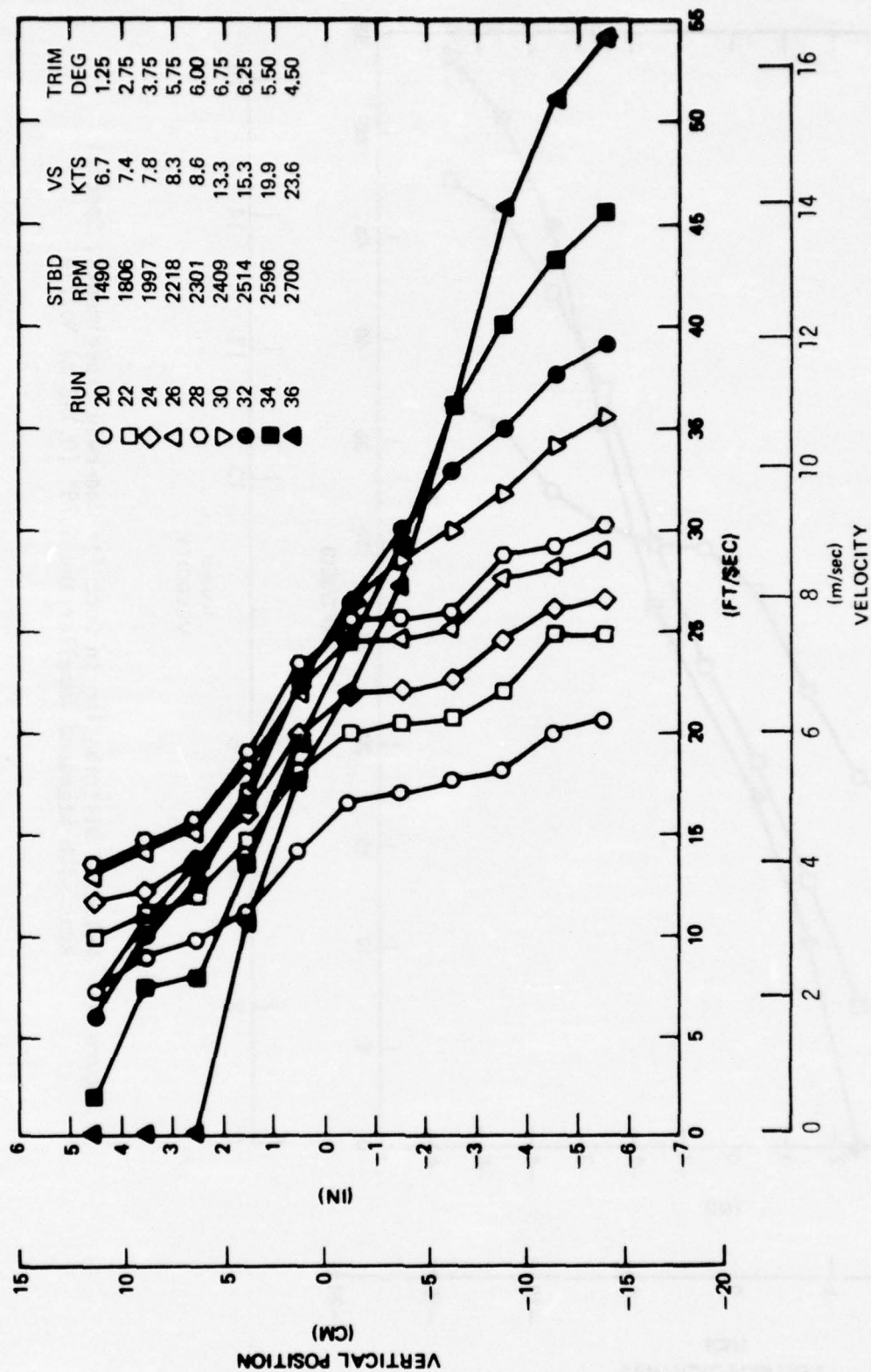


Figure 9 - Velocity Distribution Across Duct for Underway Experiments with Standard Impeller and 5.75" (0.146 m) Nozzle

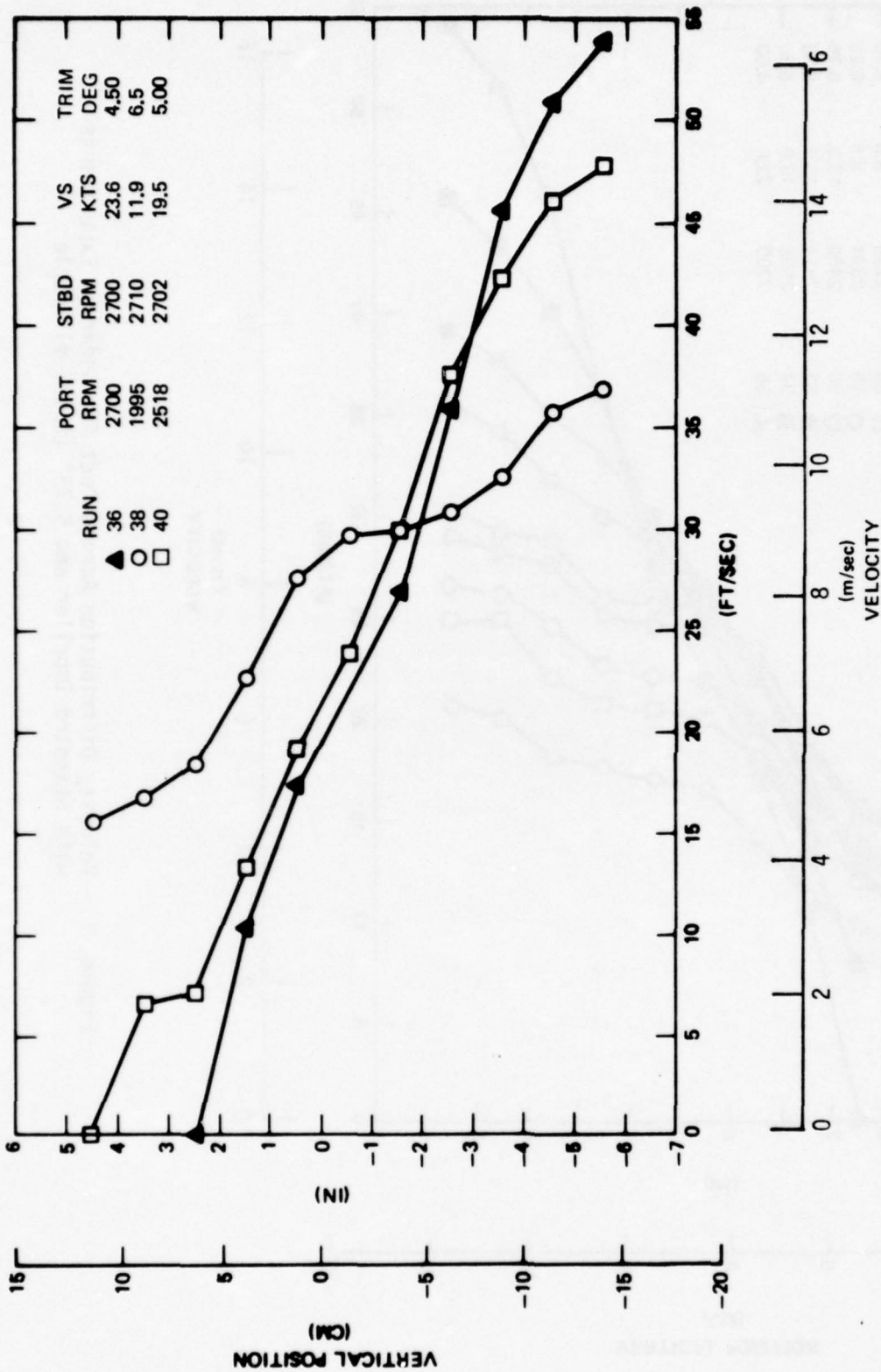


Figure 10 - Velocity Distribution in Duct for Underway Experiments, Special Runs with Standard Impeller and 5.75" (0.146 m) Nozzle

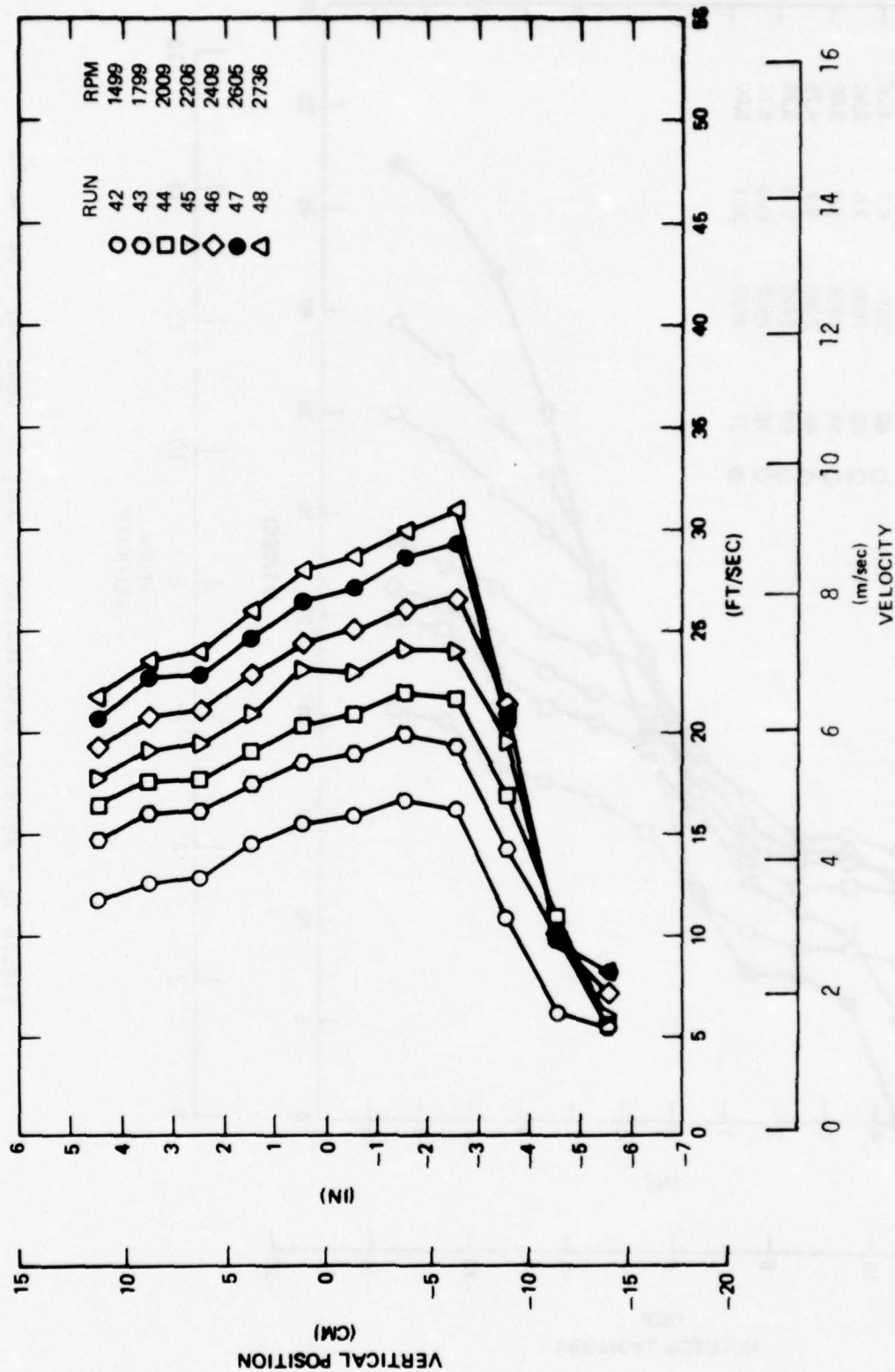


Figure 11 - Velocity Distribution in Duct for Bollard Experiments with Standard Impeller and 5.75" (0.146 m) Nozzle

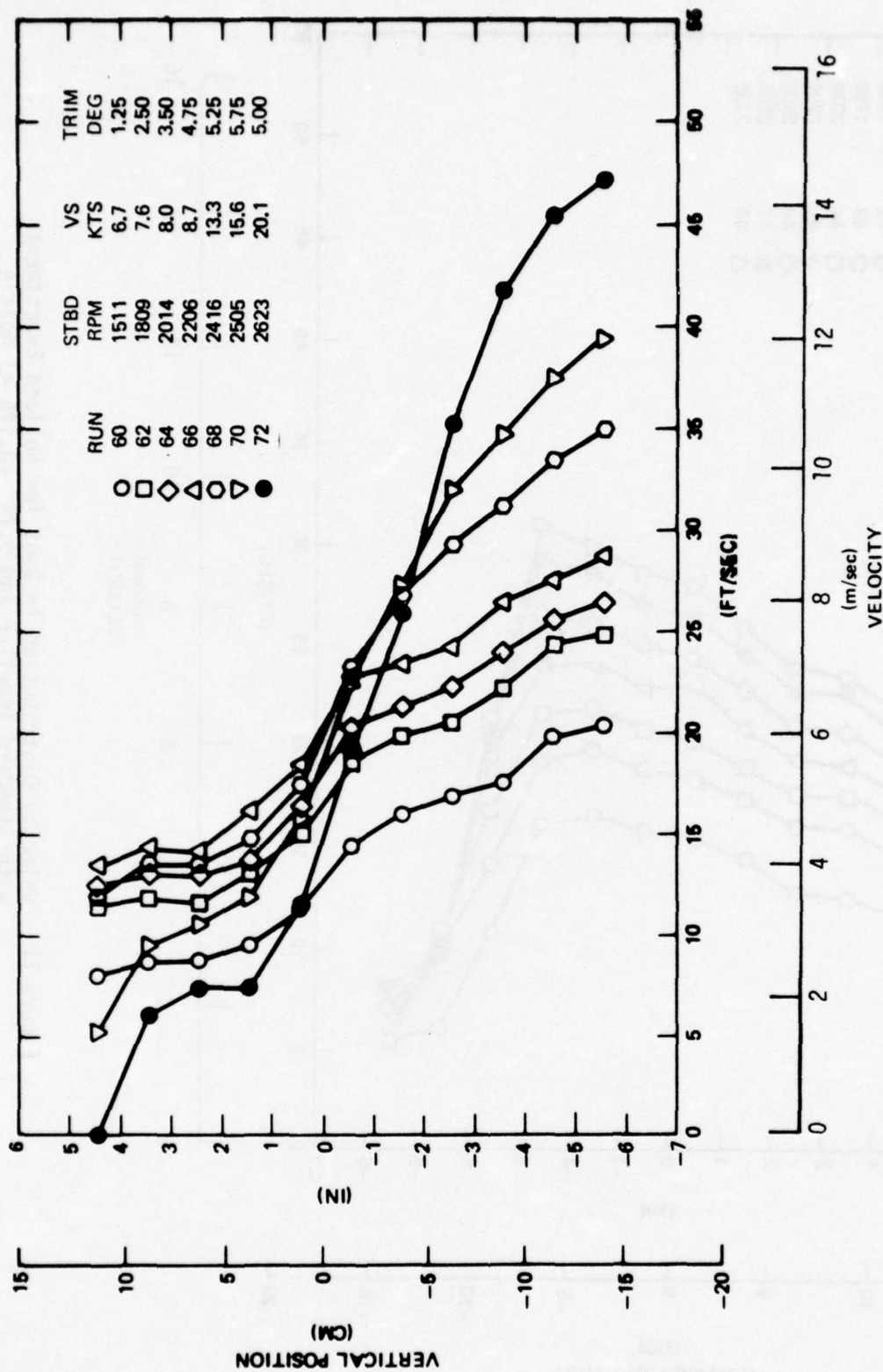


Figure 12 - Velocity Distribution in Duct for Underway Experiments with DTNSRDC Impeller and 5.75" (0.146 m) Nozzle

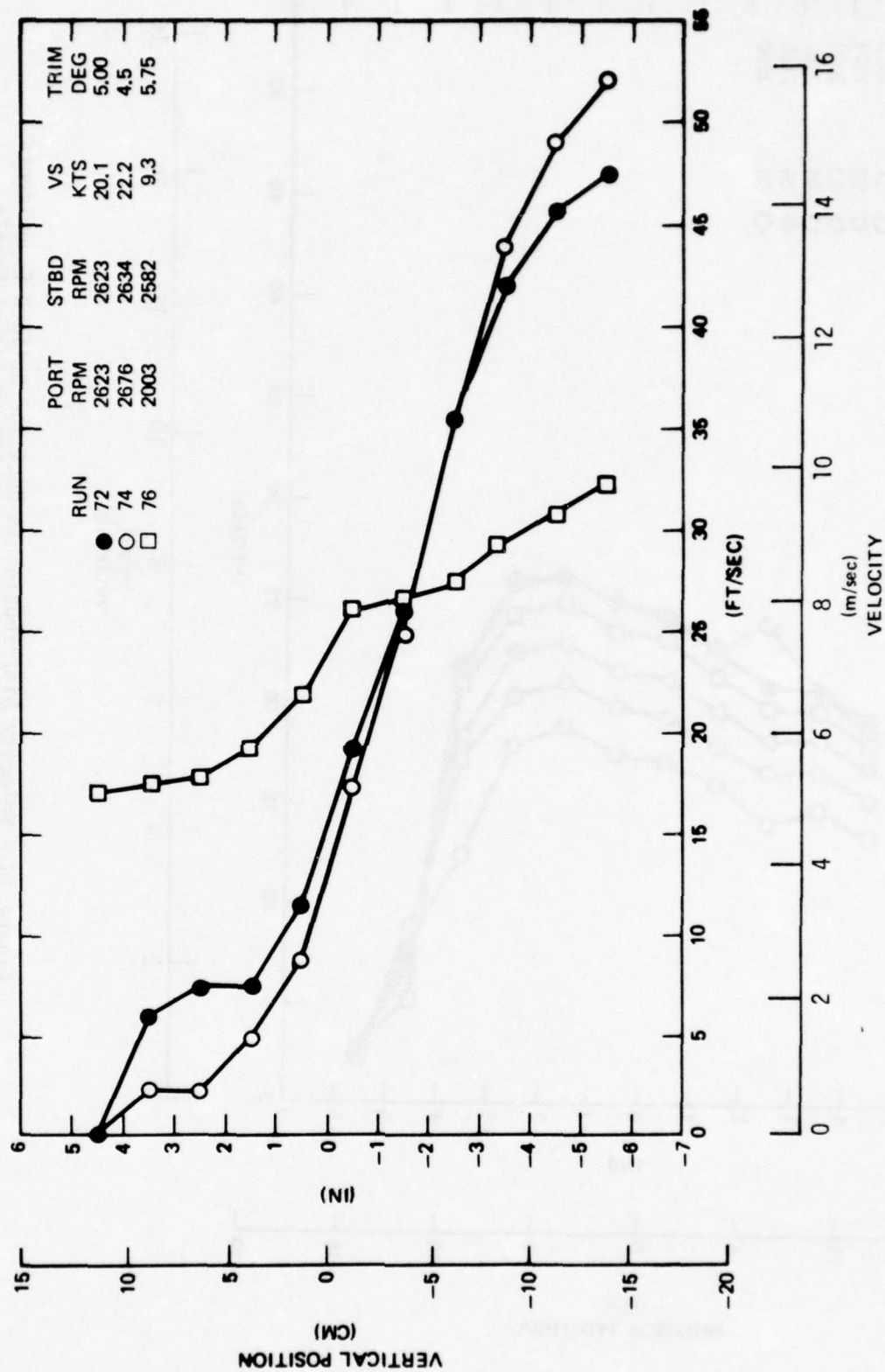


Figure 13 - Velocity Distribution in Duct for Underway Experiments, Special Runs with DTNSRDC Impeller and 5.75" (0.146 m) Nozzle

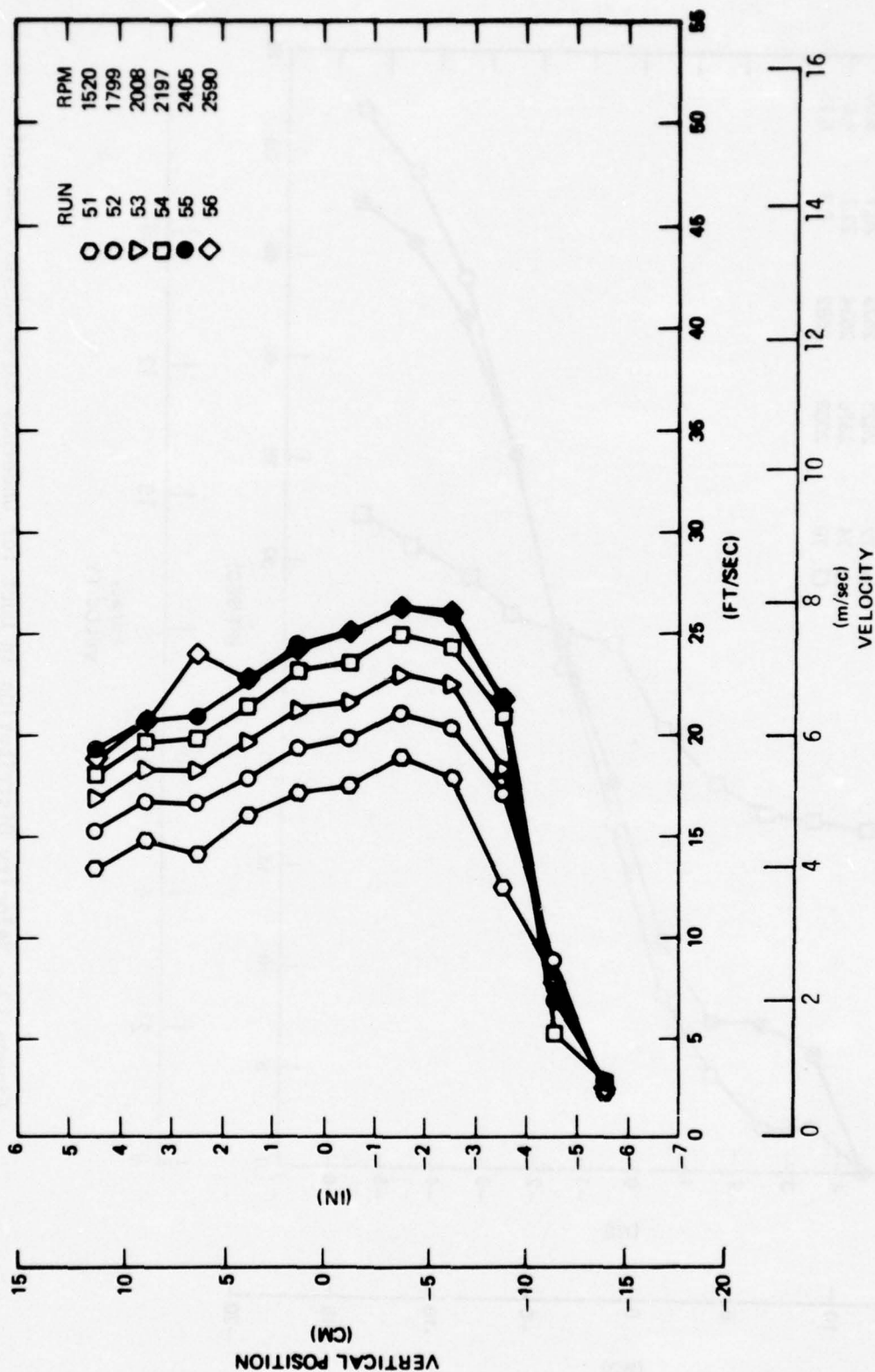


Figure 14 - Velocity Distribution in Duct for Bollard Experiments with DTNSRDC Impeller and 5.75" (0.146 m) Nozzle

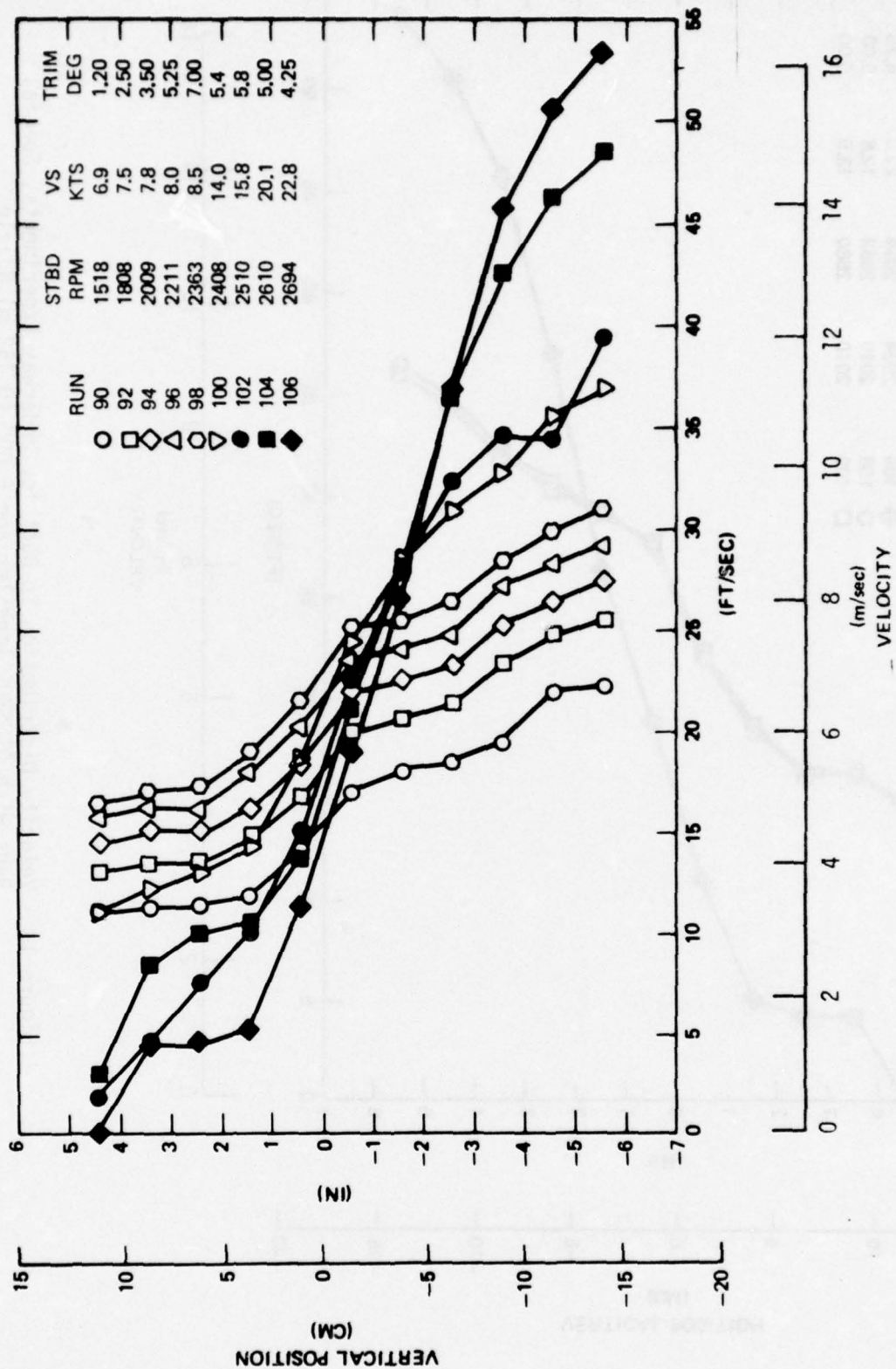


Figure 15 - Velocity Distribution in Duct for Underway Experiments with DTNSRDC Impeller and 6.00" (0.152 m) Nozzle

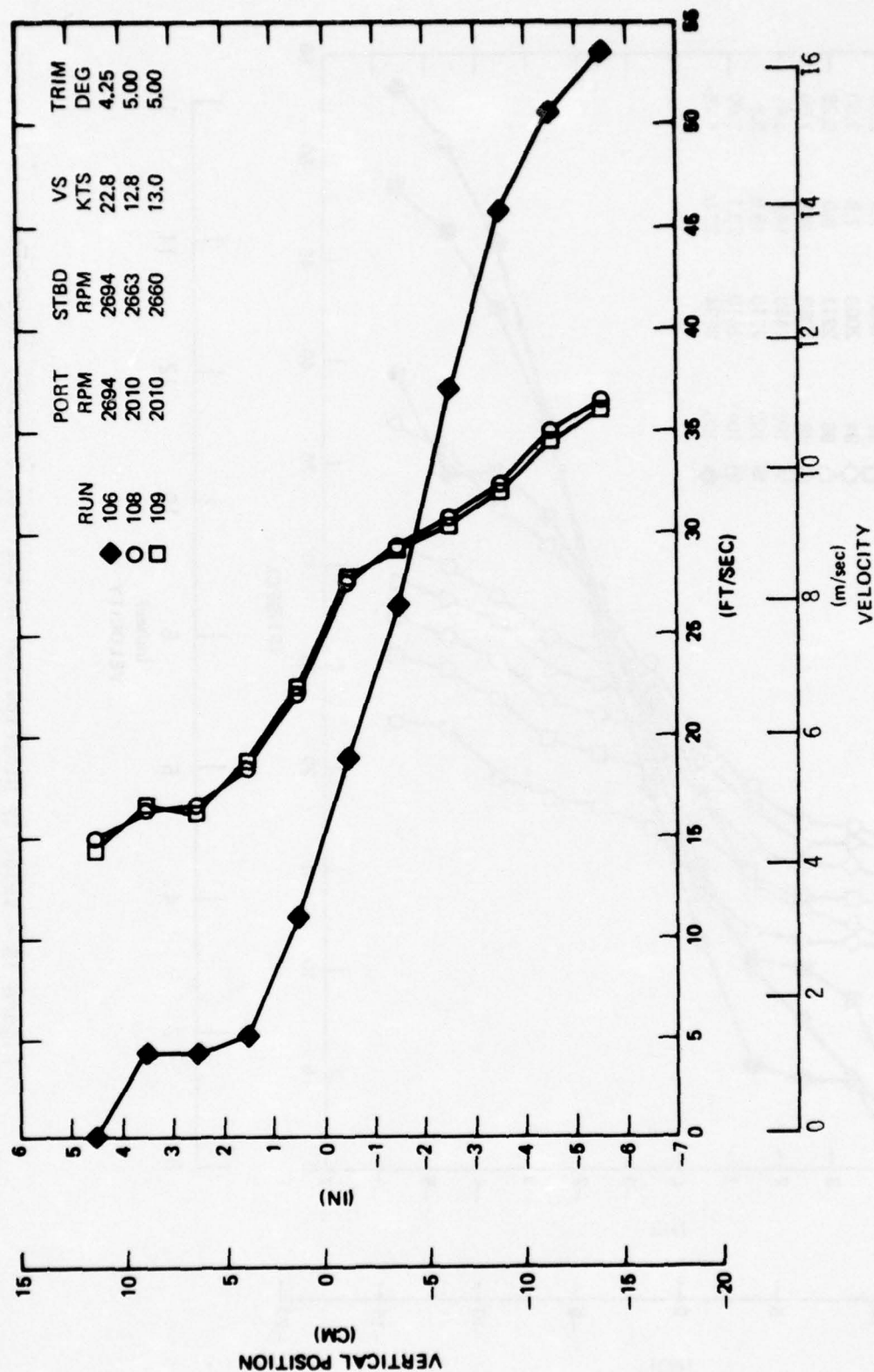


Figure 16 - Velocity Distribution in Duct for Underway Experiments, Special Runs with DTNSRDC Impeller and 6.00" (0.152 m) Nozzle

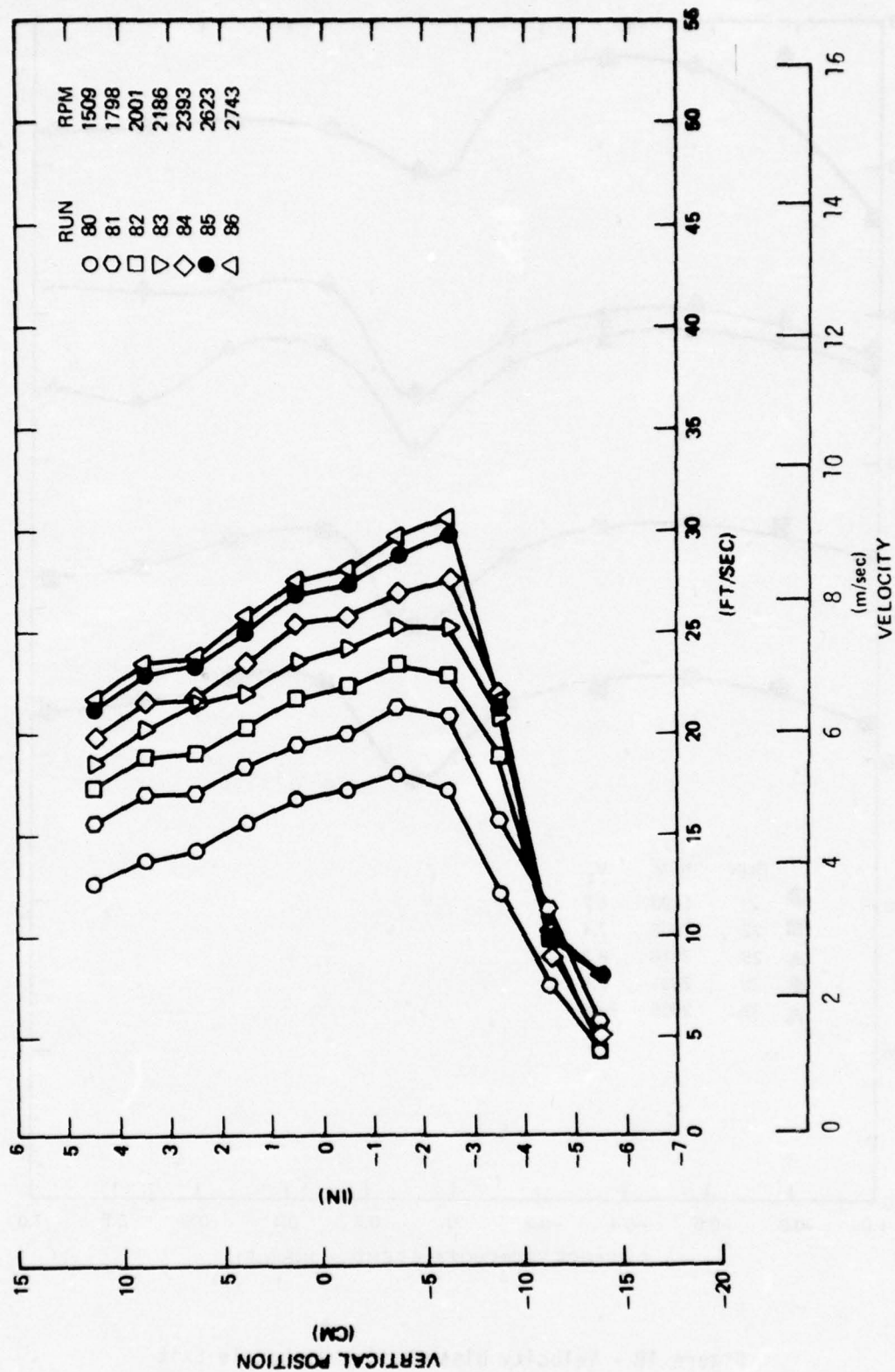


Figure 17 - Velocity Distribution in Duct for Bollard Experiments with DTNSRDC Impeller and 6.00" (0.152 m) Nozzle

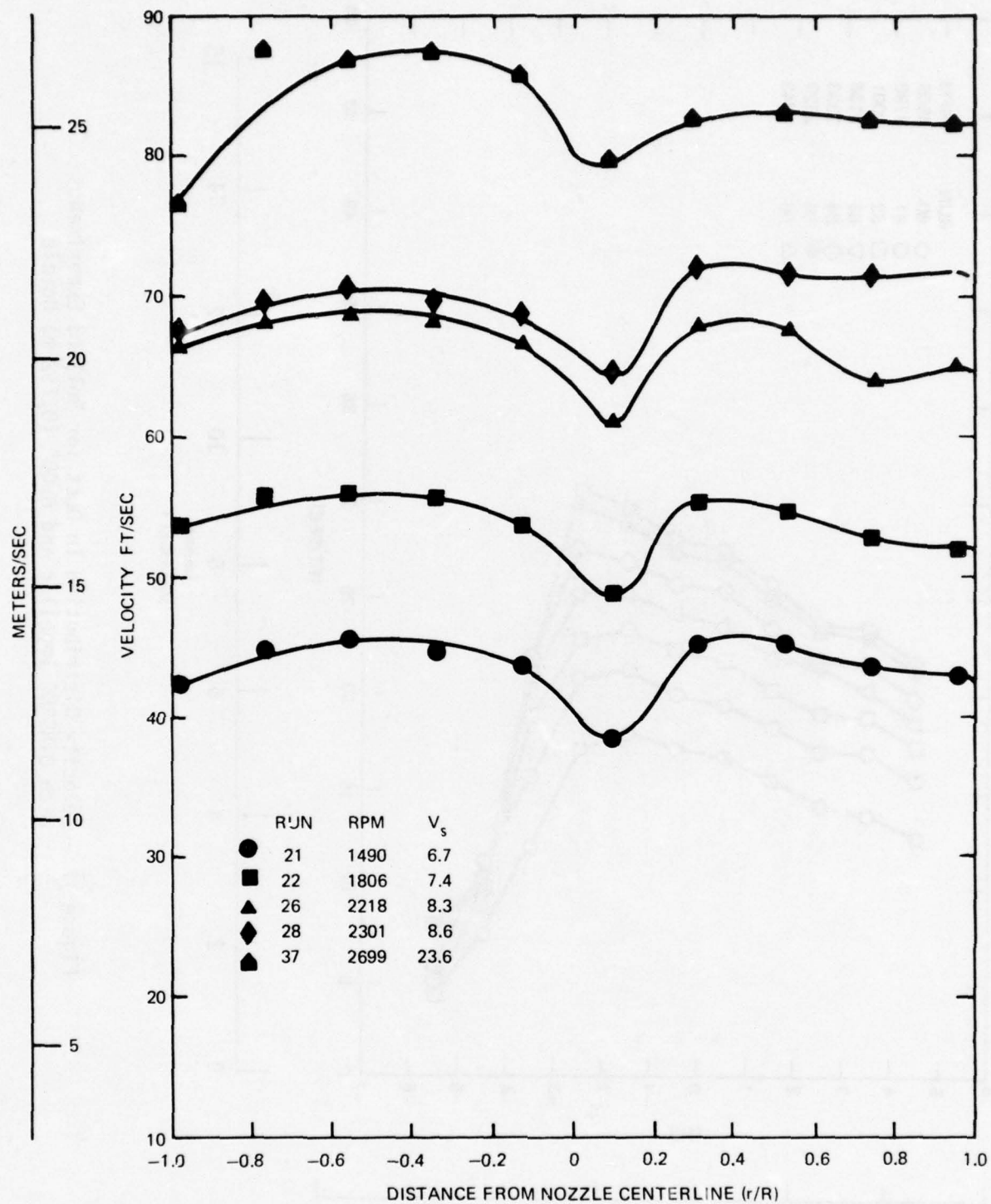


Figure 18 - Velocity Distribution at Nozzle Exit

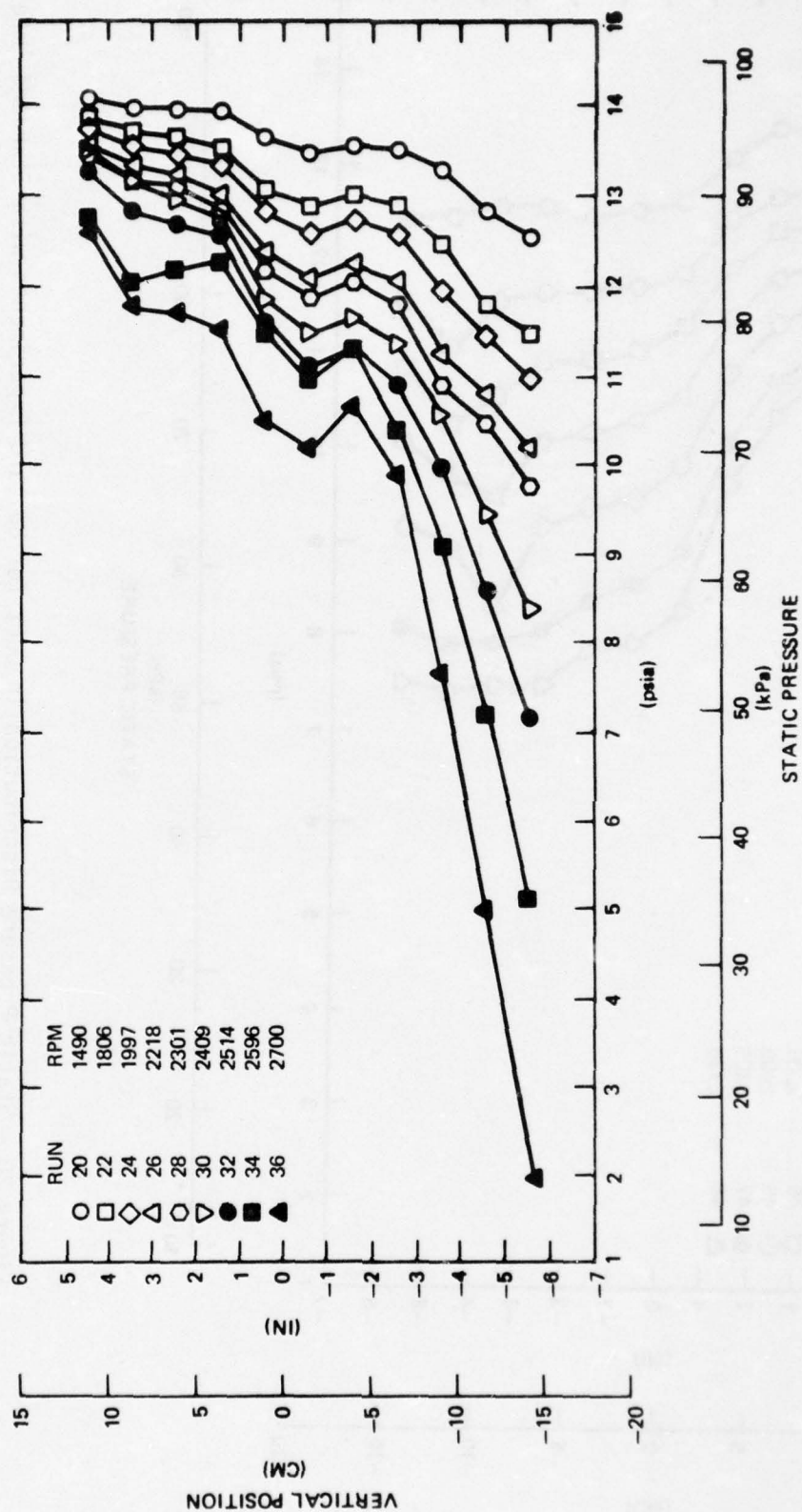


Figure 19 - Static Pressure Distribution in Duct for Underway Experiments with Standard Impeller

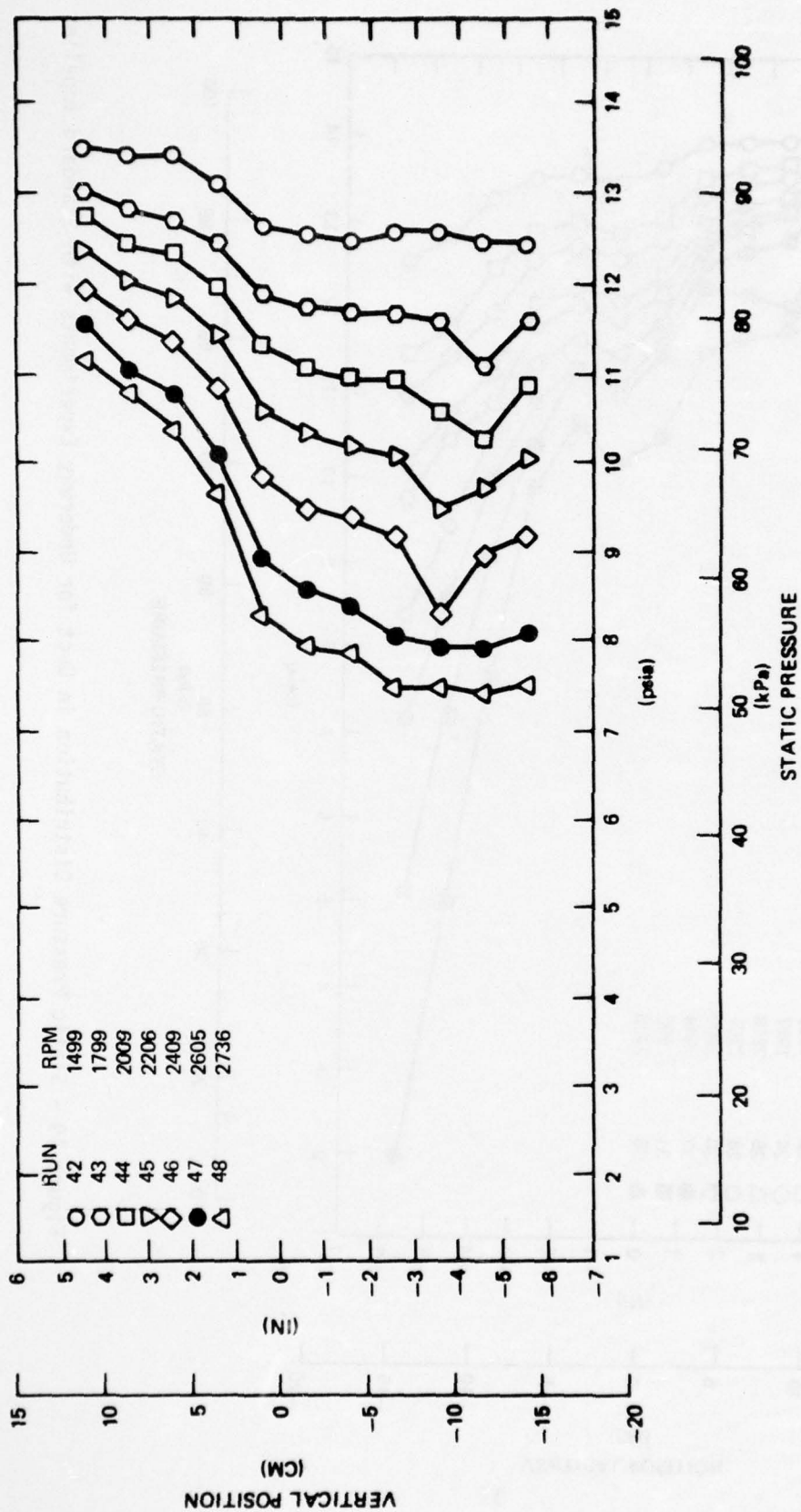


Figure 20 - Static Pressure Distribution in Duct for Bollard Experiments with Standard Impeller

TABLE 1 - TEST CRAFT

Length	31 ft (9.45 m)
Beam	10 ft 7 in. (3.23 m)
Weight.....	15,600 lb (69,392 N)
Construction	V-Bottom Planing Hull
Propulsion	2 Diesel Engines 216 HP (161 kW) at 2800 rpm

TABLE 2 - WATERJET STANDARD IMPELLER

Number of Blades	3
Maximum Diameter	11.85 in. (0.301 m)
Expanded Blade Area Ratio A_E/A_O7758

x	P/D	f_M/c	c/D	t/D
.5	1.0067	.0317	.7879	.0283
.6	.9632	.0299	.8718	.0275
.7	.9141	.0270	.9456	.0285
.8	.8584	.0239	1.0125	.0292
.9	.8728	.0173	.7024	.0311
1.0	----	----	0	.0051*

*NOTE: The extreme outer diameter of the impeller contacts the wear ring at a single point.

TABLE 3 - DTNSRDC NEW DESIGN IMPELLER

Number of Blades	4
Maximum Diameter	11.85 in. (0.301 m)
Expanded Blade Area Ratio A_E/A_O7758
Rake Angle	-15.2 deg

x	P/D	f_M/c	c/D	t/D
.5	.8425	.0322	.5904	.0250
.6	.8410	.0336	.6600	.0250
.7	.8430	.0343	.7130	.0250
.8	.8540	.0347	.7595	.0256
.9	.9150	.0365*	.5268*	.0270
1.0	1.0500	.0500*	.4238*	.0051*

*NOTE: Approximation, the blades were cut to fit the wear ring.

TABLE 4 - OUTLINE OF EXPERIMENTAL DATA

Run No.	Stbd. rpm	Velocity knots	Trim deg	Impeller Type	Nozzle Diameter	Comments
20	1490	6.7	1.25	Standard	5.75 in. (0.146 m)	Runs 20 to 41, Static (Port) Pressure Probe Measurements Were In Error
21	1490	6.7	1.25			
22	1806	7.4	2.75			
23	1803	7.4	2.75			
24	1997	7.8	3.75			
25	1996	7.8	3.75			
26	2218	8.3	5.75			
27	2213	8.3	5.75			
28	2301	8.6	6.00			
29	2296	8.6	6.00			
30	2409	13.3	6.75			
31	2408	13.3	6.75			
32	2514	15.3	6.25			
33	2516	15.3	6.25			
34	2596	19.9	5.50			
35	2591	19.9	5.50			
36	2700	23.6	4.50			
37	2699	23.6	4.50			
38	2710	11.9	6.50			
39	2700	13.4	5.75			
40	2702	19.5	5.00			
41	2701	21.9	5.00			Port rpm 1995 Port rpm 1925 Port rpm 2518 Port rpm 2512
42	1499	0.0	0.00			
43	1799	0.0	0.00			
44	2009	0.0	0.00			
45	2206	0.0	0.00			
46	2409	0.0	0.00			

COPY AVAILABLE TO DDC DOES NOT
PERMIT FULLY LEGIBLE PRODUCTION

Port rpm 2676
Port rpm 2678
Port rpm 2003
Port rpm 2000

TABLE 4 - Continued

Run No.	Stbd. rpm	Velocity knots	Trim deg	Impeller Type	Nozzle Diameter	Comments
47	2605	0.0	0.00	Standard	5.75 in. (0.146 m)	
48	2736	0.0	0.00	DTNSRDC		
51	1520	0.0	0.00			
52	1799	0.0	0.00			
53	2008	0.0	0.00			
54	2197	0.0	0.00			
55	2405	0.0	0.00			
56	2590	0.0	0.00			
60	1511	6.7	1.25			
61	1507	6.7	1.25			
62	1809	7.6	2.50			
63	1806	7.6	2.50			
64	2014	8.0	3.50			
65	2013	8.0	3.50			
66	2206	8.7	4.75			
67	2203	8.7	4.75			
68	2416	13.3	5.25			
69	2410	13.3	5.25			
70	2505	15.6	5.75			
71	2504	15.6	5.75			
72	2623	20.1	5.00			
74	2634	22.2	4.50			
75	2629	22.3	4.50			
76	2582	9.3	5.75			
77	2578	9.3	6.00			

TABLE 4 - Continued

Run No.	Stbd. rpm	Velocity knots	Trim deg	Impeller Type	Nozzle Diameter	Comments
80	1509	0.0	0.00	DTNSRDC	6.00 in. (0.1524 m)	
81	1798	0.0	0.00			
82	2001	0.0	0.00			
83	2186	0.0	0.00			
84	2393	0.0	0.00			
85	2623	0.0	0.00			
86	2743	0.0	0.00			
90	1518	6.9	1.20			
91	1516	6.9	1.20			
92	1808	7.5	2.50			
93	1808	7.5	2.50			
94	2009	7.8	3.50			
95	2010	7.8	3.50			
96	2211	8.0	5.25			
97	2207	8.0	5.25			
98	2363	8.5	7.00			
99	2362	13.2	5.30			
100	2408	14.0	5.40			
101	2400	14.0	5.20			
102	2510	15.8	5.80			
103	2510	15.8	6.00			
104	2610	20.1	5.00			
105	2610	20.1	5.00			
106	2694	22.8	4.25			
107	2698	22.8	4.25			
108	2663	12.8	5.00			
109	2660	13.0	5.00			

Craft was not planing

Port rpm 2010
Port rpm 2010

TABLE 5 - UNDERWAY EXPERIMENTS WITH STANDARD IMPELLER AND 5.75 IN. (0.146 m) NOZZLE

Run No. 20	PORT				STARBOARD			
POSITION	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
1		14.84		14.08	14.41	6.96		44.50
2		14.76		13.97	14.49	8.68		47.08
3		14.60		13.96	14.57	9.37		47.45
4		14.64		13.92	14.74	10.89		47.01
5		14.84		13.65	14.99	13.93		45.87
6		15.35		13.49	15.26	16.03		39.31
7		15.64		13.58	15.48	16.57		46.86
8		15.68		13.53	15.57	17.18		46.75
9		15.63		13.30	15.48	17.75		45.33
10		15.71		12.83	15.53	19.76		44.56
11		15.54		12.53	15.34	20.14		0.00

Run No. 21	PORT				STARBOARD			
POSITION	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
1		14.64		14.08	14.47	7.46		42.34
2		14.47		13.99	14.53	8.88		44.93
3		14.34		13.97	14.57	9.30		45.25
4		14.38		13.89	14.78	11.33		44.77
5		14.55		13.66	15.02	14.06		43.87
6		15.00		13.49	15.27	16.05		38.22
7		15.03		13.57	15.50	16.71		45.33
8		14.83		13.54	15.65	17.46		45.07
9		14.84		13.33	15.54	17.89		43.71
10		14.84		12.82	15.56	19.90		43.04
11		14.84		12.56	15.39	20.24		0.00

Run No. 22

POSITION	STATIC PRESSURE PSIA	PORT TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	STARBOARD TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
1		14.95		13.87	14.49	9.51		53.83
2		14.82		13.71	14.50	10.66		55.79
3		14.61		13.66	14.58	11.52		55.90
4		14.70		13.52	14.94	14.34		55.62
5		14.90		13.06	15.27	17.86		53.82
6		15.64		12.89	15.57	19.68		48.81
7		16.27		13.02	15.80	20.05		55.34
8		15.99		12.91	15.81	20.48		54.86
9		15.97		12.47	15.78	21.86		52.86
10		16.07		11.78	15.97	24.60		52.33
11		15.60		11.47	15.65	24.60		0.00

Run No. 23

POSITION	STATIC PRESSURE PSIA	PORT TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	STARBOARD TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
1		14.33		13.83	14.56	10.27		52.21
2		14.21		13.68	14.59	11.43		54.99
3		14.03		13.65	14.68	12.23		55.29
4		14.08		13.53	14.96	14.38		55.81
5		14.37		13.13	15.29	17.64		55.81
6		15.13		12.94	15.65	19.81		50.06
7		15.48		13.08	15.91	20.24		57.10
8		15.50		12.98	15.94	20.71		56.44
9		15.49		12.53	15.90	22.07		54.69
10		15.59		11.84	16.09	24.77		54.11
11		15.19		11.56	15.71	24.50		0.00

Run No. 24

POSITION	PORT		STARBOARD		AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA		
1		15.15	13.74	14.62	11.28	
2		15.00	13.55	14.54	11.98	
3		14.78	13.46	14.68	13.29	
4		14.73	13.31	15.05	15.87	
5		15.08	12.80	15.44	19.55	
6		15.95	12.57	15.83	21.70	
7		16.26	12.71	16.01	21.84	
8		16.25	12.57	16.03	22.38	
9		16.24	11.93	16.03	24.34	
10		16.14	11.41	15.99	25.73	
11		15.79	10.94	15.75	26.35	

Run No. 25

POSITION	PORT		STARBOARD		AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA		
1		14.93	13.73	14.69	11.76	56.49
2		14.81	13.54	14.64	12.62	58.71
3		14.58	13.51	14.69	13.07	60.50
4		14.55	13.34	15.09	15.90	59.97
5		14.82	12.82	15.47	19.57	58.28
6		15.77	12.63	15.85	21.57	50.61
7		16.11	12.74	16.13	22.16	57.29
8		16.10	12.60	16.09	22.48	56.77
9		15.51	12.44	15.59	21.32	59.69
10		16.11	11.46	16.07	25.83	55.03
11		15.70	10.97	15.79	26.41	0.00

Run No. 26

POSITION	STATIC PRESSURE PSIA	PORT TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	STARBOARD TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
1		15.28		13.58	14.70	12.69		66.23
2		15.10		13.33	14.68	13.98		68.07
3		14.80		13.21	14.74	14.89		68.60
4		14.83		13.00	15.26	18.05		68.07
5		15.15		12.36	15.70	21.97		66.70
6		16.24		12.07	16.13	24.21		60.94
7		16.39		12.23	16.28	24.19		68.00
8		16.34		12.05	16.28	24.71		67.41
9		16.38		11.21	16.34	27.23		63.84
10		16.25		10.77	16.18	27.98		64.96
11		15.86		10.15	15.81	28.60		14.63

Run No. 27

POSITION	STATIC PRESSURE PSIA	PORT TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	STARBOARD TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
1		15.05		13.58	14.73	12.87		64.45
2		14.95		13.35	14.70	13.98		68.59
3		14.64		13.27	14.84	15.08		69.72
4		14.54		13.05	15.28	17.98		69.28
5		15.01		12.46	15.80	21.99		67.99
6		16.10		12.17	16.19	24.08		62.42
7		16.37		12.29	16.40	24.36		69.25
8		16.36		12.16	16.35	24.61		68.88
9		16.36		11.29	16.42	27.23		67.36
10		16.25		10.88	16.23	27.81		66.88
11		15.78		10.23	15.85	28.51		19.46

COPY AVAILABLE TO DDC DOES NOT
PERMIT FULLY LEGIBLE PRODUCTION

Run No. 28		PORT				STARBOARD			
POSITION	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC	
1		15.31		13.44	14.62	13.04		67.33	
2		15.07		13.16	14.57	14.29		69.52	
3		14.83		13.10	14.73	15.34		70.50	
4		14.81		12.85	15.26	18.68		69.87	
5		15.06		12.14	15.83	23.07		68.60	
6		16.18		11.83	16.20	25.11		64.31	
7		16.38		12.03	16.35	25.01		72.25	
8		16.36		11.79	16.35	25.66		71.45	
9		16.39		10.88	16.46	28.40		71.51	
10		16.25		10.44	16.24	28.94		86.23	
11		15.85		9.73	15.87	29.80		44.49	

Run No. 29		PORT				STARBOARD			
POSITION	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC	
1		15.10		13.47	14.74	13.55			
2		14.92		13.25	14.56	13.80			
3		14.53		13.15	14.78	15.34			
4		14.56		12.90	15.31	18.65			
5		15.41		12.21	15.85	22.95			
6		16.11		11.93	16.25	24.98			
7		16.42		12.13	16.47	25.04			
8		16.32		11.93	16.40	25.42			
9		16.45		11.01	16.55	28.32			
10		16.33		10.51	16.26	28.83			
11		15.79		9.85	15.89	29.55			

COPY AVAILABLE TO DDC DOES NOT
PERMIT FULLY LEGIBLE PRODUCTION

Run No. 30

POSITION	STATIC PRESSURE PSIA	PORT TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	STARBOARD TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
1		14.40		13.49	13.83	7.05		
2		14.18		13.14	13.89	10.42		
3		14.01		12.97	14.19	13.25		
4		14.19		12.77	14.70	16.73		
5		14.75		11.82	15.27	22.33		
6		16.13		11.44	16.06	25.85		
7		17.27		11.64	17.14	28.19		
8		17.57		11.35	17.46	29.72		
9		17.38		10.53	17.35	31.40		
10		17.33		9.41	17.35	33.88		
11		16.73		8.33	16.85	35.09		

Run No. 31

POSITION	STATIC PRESSURE PSIA	PORT TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	STARBOARD TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
1		14.03		13.45	13.83	7.36		
2		13.89		13.03	13.88	11.05		
3		13.67		12.93	14.03	12.63		
4		14.02		12.77	14.65	16.49		
5		14.79		11.94	15.14	21.52		
6		15.96		11.48	16.06	25.75		
7		17.54		11.76	17.30	28.29		
8		17.72		11.40	17.68	30.15		
9		17.72		10.47	17.76	32.46		
10		17.71		9.23	17.83	35.26		
11		17.08		7.89	17.31	36.91		

Run No. 32

POSITION	STATIC PRESSURE PSIA	PORT TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	STARBOARD TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
1		13.54		13.25	13.49	5.86		
2		13.49		12.80	13.44	9.57		
3		13.36		12.67	13.71	12.26		
4		13.58		12.52	14.35	16.27		
5		14.20		11.58	14.90	21.92		
6		16.26		11.07	15.77	26.07		
7		17.70		11.29	17.39	29.69		
8		18.53		10.88	18.22	32.56		
9		18.32		9.93	18.19	34.55		
10		18.19		8.56	18.21	37.34		
11		17.53		7.11	17.50	38.76		

Run No. 33

POSITION	STATIC PRESSURE PSIA	PORT TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	STARBOARD TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
1		13.08		13.02	13.22	5.36		
2		13.06		12.50	13.03	8.73		
3		12.87		12.53	13.29	10.48		
4		13.05		12.47	13.95	14.60		
5		14.08		11.69	14.56	20.36		
6		15.77		11.15	15.59	25.34		
7		17.65		11.36	17.33	29.39		
8		17.96		10.87	18.53	33.28		
9		17.96		9.76	18.74	36.04		
10		18.67		8.16	18.78	39.18		
11		18.01		6.42	18.09	41.07		

COPY AVAILABLE TO DDC DOES NOT
PERMIT FULLY LEGIBLE PRODUCTION

Run No. 34

POSITION	STATIC PRESSURE PSIA	PORT TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	STARBOARD TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
1		12.55		12.74	12.76	1.61		
2		12.51		12.00	12.34	7.07		
3		12.40		12.14	12.53	7.57		
4		12.53		12.26	13.44	13.10		
5		13.63		11.46	14.04	19.32		
6		15.11		10.91	14.93	24.10		
7		17.45		11.28	16.95	28.62		
8		19.48		10.36	19.21	35.77		
9		19.97		9.05	19.96	39.72		
10		19.92		7.18	19.91	42.91		
11		19.09		5.08	19.23	45.22		

Run No. 35

POSITION	STATIC PRESSURE PSIA	PORT TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	STARBOARD TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
1		11.75		12.66	12.39	0.00		
2		11.63		11.92	11.97	2.69		
3		11.75		11.81	11.91	3.88		
4		12.10		11.83	12.68	11.06		
5		13.01		11.16	13.04	16.49		
6		14.05		10.77	13.86	21.12		
7		16.60		11.11	15.85	26.20		
8		19.48		10.15	18.62	35.00		
9		21.60		8.23	21.27	43.42		
10		22.02		5.88	21.90	48.12		
11		20.55		4.55	20.69	48.32		

Run No. 36

POSITION	PORT		STARBOARD		AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA		
1		11.47	12.58	12.21	0.00	77.23
2		11.61	11.72	11.55	0.00	85.45
3		11.66	11.68	11.47	0.00	84.71
4		11.87	11.46	12.22	10.44	85.17
5		12.47	10.47	12.54	17.29	84.44
6		13.62	10.13	13.41	21.75	68.83
7		16.24	10.63	15.67	26.97	78.18
8		20.59	9.87	18.62	35.58	81.08
9		22.57	7.61	21.91	45.47	77.60
10		22.80	4.95	22.83	50.85	77.93
11		21.53	1.90	22.02	53.93	46.27

Run No. 37

POSITION	PORT		STARBOARD		AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA		
1		11.25	12.19	11.69	0.00	76.27
2		11.47	11.48	11.26	0.00	87.52
3		11.42	11.33	10.97	0.00	86.49
4		11.62	11.06	11.62	9.01	87.12
5		12.10	9.90	11.74	16.34	85.43
6		13.37	9.95	13.02	21.05	79.60
7		15.91	10.63	15.08	25.37	82.26
8		19.74	9.30	18.64	36.73	82.94
9		24.26	7.32	22.15	46.30	82.27
10		23.91	4.14	23.80	53.30	82.17
11		22.58	2.74	22.72	53.74	81.74

TABLE 6 - UNDERWAY EXPERIMENTS, SPECIAL RUNS WITH STANDARD IMPELLER AND 5.75 IN. (0.146 m) NOZZLE

Run No. 38

POSITION	STATIC PRESSURE PSIA	PORT TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	STARBOARD TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
1		15.48		13.02	14.72	15.70		
2		15.21		12.65	14.63	16.92		
3		14.85		12.47	14.84	18.50		
4		14.79		12.00	15.57	22.74		
5		15.12		11.01	16.29	27.64		
6		16.75		10.61	16.73	29.74		
7		16.99		10.81	16.96	29.83		
8		17.24		10.45	17.00	30.80		
9		17.20		9.71	17.02	32.50		
10		17.34		8.43	17.18	35.58		
11		16.64		7.21	16.66	36.98		

Run No. 39

POSITION	STATIC PRESSURE PSIA	PORT TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	STARBOARD TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
1		15.28		13.04	14.59	15.01		
2		14.85		12.66	14.25	15.21		
3		14.00		12.48	14.24	15.94		
4		14.11		12.24	14.93	19.73		
5		14.93		11.12	15.84	26.11		
6		16.84		10.62	16.75	29.78		
7		17.74		10.91	17.49	30.83		
8		17.84		10.53	17.67	32.14		
9		17.64		9.61	17.45	33.66		
10		17.60		8.36	17.46	36.28		
11		16.85		6.98	16.91	37.89		

COPY AVAILABLE TO DDC DOES NOT
NECESSARILY REPRESENT FULLY LEGIBLE PRODUCTION

Run No. 40

POSITION	PORT		STARBOARD		NOZZLE VELOCITY FT/SEC
	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	
1		12.23	12.55	12.52	0.00
2		12.01	11.72	12.02	6.66
3		11.90	11.77	12.12	7.06
4		12.38	11.87	13.12	13.47
5		13.51	11.10	13.64	19.18
6		15.06	10.60	14.53	23.85
7		17.37	10.76	16.96	29.93
8		20.04	9.92	19.64	37.50
9		20.78	8.37	20.75	42.31
10		20.80	6.19	20.83	46.01
11		19.73	4.11	19.91	47.80

Run No. 41

POSITION	PORT		STARBOARD		NOZZLE VELOCITY FT/SEC
	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	
1		11.73	12.52	12.29	0.00
2		11.74	11.68	11.79	4.01
3		11.79	11.51	11.58	3.15
4		12.02	11.61	12.57	11.82
5		12.88	10.88	13.05	17.69
6		14.51	10.55	13.76	21.54
7		16.89	10.78	16.08	27.68
8		20.05	9.62	19.15	37.12
9		22.20	7.71	21.84	45.20
10		22.53	5.09	22.62	50.35
11		21.36	2.69	21.33	51.91

Run No. 44	PORT				STARBOARD			
POSITION	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
1	12.65	14.75	17.38	12.77	14.38	15.26	16.32	
2	12.39	14.72	18.34	12.44	14.41	16.88	17.61	
3	12.21	14.38	17.71	12.32	14.45	17.57	17.64	
4	12.29	14.84	19.19	11.97	14.43	18.83	19.01	
5	12.20	14.89	19.70	11.30	14.33	20.93	20.32	
6	12.03	14.75	19.82	11.04	14.41	22.06	20.94	
7	11.77	14.88	21.20	10.94	14.52	22.74	21.97	
8	11.32	14.78	22.34	10.92	13.95	20.93	21.63	
9	10.78	13.50	19.82	10.55	11.90	13.96	16.89	
10	10.70	11.78	12.50	10.23	10.82	9.23	10.86	
11	10.94	11.47	8.76	10.84	10.88	2.47	5.61	

Run No. 45	PORT				STARBOARD			
POSITION	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
1	12.26	14.70	18.78	12.40	14.33	16.72	17.75	
2	11.96	14.60	19.53	12.03	14.42	18.57	19.05	
3	11.65	14.32	19.64	11.85	14.44	19.34	19.49	
4	11.69	14.74	21.02	11.41	14.39	20.76	20.89	
5	11.65	15.29	22.91	10.58	14.30	23.19	23.05	
6	11.49	14.74	21.67	10.32	14.37	24.18	22.93	
7	11.17	14.86	23.10	10.17	14.52	25.07	24.09	
8	10.54	14.82	24.85	10.06	13.77	23.15	24.00	
9	9.73	13.36	22.92	9.46	11.31	16.34	19.63	
10	10.13	11.14	12.06	9.68	10.16	8.32	10.19	
11	10.18	10.72	8.84	10.01	10.08	3.21	6.02	

**COPY AVAILABLE TO DDC DOES NOT
PERMIT FULLY LEGIBLE PRODUCTION**

Run No. 46

POSITION	PORT			STARBOARD			NOZZLE VELOCITY FT/SEC
	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	
1	11.85	14.67	20.20	11.95	14.28	18.34	19.27
2	11.48	14.68	21.50	11.60	14.38	20.02	20.76
3	11.11	14.20	21.12	11.36	14.39	20.94	21.03
4	11.08	14.74	22.98	10.81	14.37	22.67	22.82
5	11.04	14.84	23.42	9.81	14.26	25.38	24.40
6	10.85	14.68	23.52	9.46	14.32	26.50	25.01
7	10.48	14.82	25.07	9.37	14.45	27.11	26.09
8	9.49	14.82	27.78	9.13	13.62	25.47	26.63
9	8.96	12.79	23.52	8.27	10.86	19.35	21.43
10	9.48	10.36	11.27	8.91	9.40	8.47	9.87
11	9.18	9.89	10.12	9.15	9.28	4.31	7.22

Run No. 47

POSITION	PORT			STARBOARD			NOZZLE VELOCITY FT/SEC
	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	
1	11.32	14.65	21.94	11.54	14.14	19.39	20.67
2	10.88	14.65	23.33	11.01	14.34	21.94	22.63
3	10.42	14.01	22.76	10.77	14.37	22.82	22.79
4	10.37	14.56	24.59	10.08	14.27	24.60	24.60
5	10.36	14.74	25.15	8.92	14.24	27.74	26.44
6	10.16	14.57	25.25	8.55	14.30	28.84	27.04
7	9.60	14.81	27.45	8.37	14.44	29.62	28.53
8	8.35	14.75	30.42	8.03	13.46	28.03	29.23
9	8.32	12.18	23.59	7.93	10.06	17.56	20.57
10	8.69	9.47	10.62	7.89	8.40	8.65	9.63
11	8.21	9.04	10.94	8.03	8.27	5.88	8.41

Run No. 48

POSITION	PORT			STARBOARD			NOZZLE VELOCITY FT/SEC
	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	
1	10.99	14.64	22.95	11.13	14.01	20.43	21.69
2	10.59	14.63	24.29	10.76	14.33	22.70	23.50
3	10.06	13.94	23.69	10.36	14.38	24.11	23.90
4	9.89	14.55	25.96	9.65	14.28	25.87	25.92
5	9.84	14.77	26.70	8.29	14.18	29.17	27.94
6	9.64	14.60	26.78	7.91	14.26	30.30	28.54
7	9.05	14.66	28.99	7.82	14.38	30.80	29.89
8	7.64	14.91	32.42	7.43	13.39	29.37	30.89
9	7.89	11.67	23.39	7.48	9.80	18.34	20.86
10	8.04	8.86	10.90	7.38	7.88	8.47	9.68
11	7.52	8.47	11.72	7.46	7.61	4.71	8.21

53

TABLE 8 - UNDERWAY EXPERIMENTS WITH DTNSRDC IMPELLER AND 5.75 IN. (0.146 m) NOZZLE

Run No. 60

POSITION	PORT			STARBOARD			NOZZLE VELOCITY FT/SEC
	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	
1	13.75	14.58	10.96	14.33	14.48	4.74	7.85
2	13.66	14.47	10.78	14.21	14.49	6.39	8.59
3	13.70	14.38	9.89	14.18	14.57	7.45	8.67
4	13.74	14.39	9.69	14.12	14.71	9.21	9.45
5	13.84	14.53	9.94	13.87	14.96	12.52	11.23
6	13.77	15.06	13.76	13.71	15.24	14.88	14.32
7	13.65	15.40	15.92	13.75	15.47	15.77	15.85
8	13.45	15.43	16.90	13.70	15.59	16.54	16.72
9	13.15	15.39	18.00	13.50	15.49	16.97	17.48
10	12.66	15.47	20.15	12.96	15.53	19.27	19.71
11	12.38	15.35	20.72	12.65	15.37	19.80	20.26

COPY AVAILABLE TO DDC DOES NOT
PERMIT FULLY LEGIBLE PRODUCTION

**COPY AVAILABLE TO DDC DOES NOT
PERMIT FULLY LEGIBLE PRODUCTION**

Run No. 61

POSITION	PORT			STARBOARD			NOZZLE VELOCITY FT/SEC
	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	
1	13.55	14.43	11.29	14.38	14.41	2.10	6.69
2	13.43	14.35	11.53	14.28	14.42	4.53	8.03
3	13.48	14.22	10.34	14.27	14.48	5.54	7.94
4	13.56	14.29	10.27	14.21	14.69	8.33	9.30
5	13.70	14.47	10.55	13.96	14.93	11.84	11.20
6	13.64	15.00	14.31	13.78	15.21	14.38	14.35
7	13.54	15.35	16.18	13.83	15.48	15.47	15.82
8	13.36	15.35	16.96	13.80	15.54	15.86	16.41
9	13.03	15.33	18.22	13.58	15.42	16.31	17.26
10	12.58	15.42	20.27	13.05	15.45	18.59	19.43
11	12.25	15.30	21.00	12.77	15.26	18.99	19.99

Run No. 62

POSITION	PORT			STARBOARD			NOZZLE VELOCITY FT/SEC
	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	
1	13.72	14.95	13.34	13.97	14.57	9.28	11.31
2	13.61	14.85	13.36	13.81	14.50	10.00	11.68
3	13.64	14.55	11.45	13.73	14.64	11.52	11.49
4	13.73	14.70	11.79	13.61	14.97	14.02	12.91
5	13.87	14.92	12.36	13.19	15.29	17.41	14.88
6	13.75	15.78	17.14	12.97	15.67	19.74	18.44
7	13.60	16.09	18.97	13.07	15.95	20.39	19.68
8	13.28	16.06	20.05	12.93	15.94	20.85	20.45
9	12.77	16.04	21.73	12.46	15.92	22.34	22.04
10	12.17	16.10	23.83	11.82	16.04	24.69	24.26
11	11.82	15.84	24.09	11.39	15.80	25.25	24.67

Run No. 63

POSITION	STATIC PRESSURE PSIA	PORT TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	STARBOARD TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
1	13.58	14.83	13.43	13.97	14.62	9.70	11.57	
2	13.41	14.73	13.78	13.80	14.63	10.93	12.36	
3	13.47	14.58	12.70	13.73	14.73	12.02	12.36	
4	13.57	14.49	11.49	13.65	14.99	13.88	12.69	
5	13.74	14.62	12.52	13.23	15.37	17.61	15.06	
6	13.59	15.70	17.44	13.05	15.70	19.58	18.51	
7	13.45	15.99	19.16	13.10	15.93	20.20	19.68	
8	13.16	16.01	20.27	12.99	15.94	20.64	20.45	
9	12.69	15.97	21.78	12.55	15.91	22.04	21.91	
10	12.03	16.09	24.23	11.89	16.05	24.53	24.38	
11	11.68	15.76	24.30	11.48	15.75	24.83	24.56	

Run No. 64

POSITION	STATIC PRESSURE PSIA	PORT TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	STARBOARD TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
1	13.54	14.90	14.00	13.78	14.56	10.67	12.33	
2	13.40	14.73	13.87	13.61	14.60	11.96	12.92	
3	13.40	14.44	12.27	13.49	14.73	13.35	12.81	
4	13.50	14.43	11.59	13.39	15.07	15.62	13.60	
5	13.64	14.79	12.86	12.83	15.48	19.59	16.23	
6	13.47	15.79	18.31	12.61	15.88	21.76	20.04	
7	13.31	16.11	20.09	12.69	16.11	22.20	21.14	
8	12.97	16.19	21.57	12.56	16.10	22.60	22.09	
9	12.36	16.08	23.16	11.96	16.13	24.56	23.86	
10	11.75	16.12	25.13	11.46	16.05	25.77	25.45	
11	11.21	15.79	25.73	10.76	15.78	26.94	26.33	

**COPY AVAILABLE TO DDC DOES NOT
PERMIT FULLY LEGIBLE PRODUCTION**

Run No. 65

POSITION	STATIC PRESSURE PSIA	PORT TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	STARBOARD TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
1	13.49	14.84	13.95	13.84	14.63	10.65	12.30	
2	13.32	14.74	14.33	13.67	14.61	11.69	13.01	
3	13.32	14.54	13.26	13.56	14.69	12.74	13.00	
4	13.49	14.56	12.43	13.44	15.07	15.33	13.88	
5	13.63	14.82	13.12	12.95	15.50	19.17	16.15	
6	13.43	15.80	18.31	12.70	15.98	21.45	19.88	
7	13.32	16.15	20.23	12.78	16.11	21.94	21.09	
8	12.92	16.11	21.48	12.62	16.13	22.50	21.99	
9	12.31	16.10	23.40	12.03	16.09	24.20	23.80	
10	11.73	16.05	24.99	11.48	16.04	25.66	25.32	
11	11.15	15.79	25.87	10.82	15.77	26.74	26.30	

Run No. 66

POSITION	STATIC PRESSURE PSIA	PORT TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	STARBOARD TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
1	13.43	15.09	15.49	13.64	14.50	11.18	13.34	
2	13.19	14.98	16.06	13.43	14.48	12.33	14.20	
3	13.20	14.60	14.19	13.32	14.64	13.82	14.00	
4	13.32	14.79	14.59	13.07	15.18	17.46	16.02	
5	13.47	15.02	14.97	12.44	15.67	21.60	18.28	
6	13.27	16.27	20.81	12.11	16.16	24.18	22.50	
7	13.09	16.55	22.33	12.30	16.36	24.23	23.28	
8	12.66	16.51	23.59	12.14	16.34	24.65	24.12	
9	11.92	16.55	25.86	11.40	16.39	26.83	26.35	
10	11.28	16.37	27.12	10.86	16.14	27.62	27.37	
11	10.63	16.08	28.05	10.04	15.91	29.12	28.58	

Run No. 67

POSITION	PORT			STARBOARD			NOZZLE VELOCITY FT/SEC
	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	
1	13.41	15.01	15.19	13.66	14.49	10.98	13.08
2	13.19	14.96	16.01	13.44	14.48	12.25	14.13
3	13.14	14.57	14.37	13.33	14.64	13.72	14.04
4	13.28	14.79	14.74	13.12	15.14	17.09	15.91
5	13.45	15.05	15.20	12.47	15.66	21.46	18.33
6	13.30	17.32	24.11	12.21	16.11	23.74	23.93
7	13.12	16.60	22.43	12.37	16.34	23.95	23.19
8	12.70	16.55	23.60	12.18	16.35	24.54	24.07
9	11.93	16.56	25.88	11.45	16.37	26.66	26.27
10	11.30	16.42	27.22	10.89	16.17	27.62	27.42
11	10.58	16.09	28.22	10.04	15.87	29.02	28.62

Run No. 68

POSITION	PORT			STARBOARD			NOZZLE VELOCITY FT/SEC
	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	
1	13.26	14.63	14.08	13.53	14.15	9.47	11.77
2	12.82	14.45	15.31	13.22	14.14	11.59	13.45
3	12.78	14.04	13.49	13.06	14.29	13.31	13.40
4	13.06	14.10	12.26	12.81	14.83	17.08	14.67
5	13.42	14.55	12.76	11.94	15.26	21.90	17.33
6	13.11	16.12	20.85	11.56	15.98	25.28	23.06
7	12.87	17.37	25.49	11.83	17.18	27.81	26.65
8	12.21	17.82	28.45	11.46	17.66	29.93	29.19
9	11.26	17.72	30.56	10.69	17.60	31.61	31.09
10	10.09	17.64	33.03	9.61	17.52	33.81	33.42
11	9.03	17.11	34.18	8.17	16.95	35.62	34.90

**COPY AVAILABLE TO DDC DOES NOT
PERMIT FULLY LEGIBLE PRODUCTION**

Run No. 69	PORT				STARBOARD				
	POSITION	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
	1	13.14	14.19	12.35	13.53	13.92	7.51	9.93	
	2	12.74	13.92	13.08	13.19	13.84	9.65	11.36	
	3	12.74	13.76	12.15	13.07	14.09	12.10	12.12	
	4	13.10	14.08	11.92	12.81	14.66	16.35	14.14	
	5	13.44	14.74	13.71	12.04	15.19	21.33	17.52	
	6	13.17	16.21	20.98	11.60	16.00	25.21	23.09	
	7	12.90	17.50	25.78	11.85	17.19	27.78	26.78	
	8	12.26	18.01	28.82	11.52	17.63	29.71	29.27	
	9	11.31	17.72	30.44	10.78	17.54	31.25	30.85	
	10	10.09	17.64	33.03	9.59	17.49	33.79	33.41	
	11	8.87	17.12	34.53	8.18	17.01	35.73	35.13	

Run No. 70	POSITION	PORT			STARBOARD			AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
		STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC		
	1	12.94	13.31	7.34	13.43	13.48	2.80	5.07	
	2	12.58	13.34	10.50	12.88	13.33	8.05	9.27	
	3	12.36	13.19	10.93	12.76	13.46	10.02	10.47	
	4	12.92	13.47	8.85	12.69	14.16	14.62	11.73	
	5	13.39	14.24	11.11	11.80	14.64	20.27	15.69	
	6	13.12	15.88	19.97	11.36	15.54	24.59	22.28	
	7	12.81	17.49	26.00	11.65	17.19	28.30	27.15	
	8	12.01	18.71	31.11	11.13	18.53	32.71	31.91	
	9	10.84	18.75	33.81	10.12	18.77	35.34	34.58	
	10	9.25	18.62	36.78	8.70	18.70	38.13	37.46	
	11	7.75	18.09	38.64	6.79	17.97	40.19	39.42	

Run No. 71	PORT				STARBOARD			
POSITION	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
1	12.95	13.22	6.22	13.38	13.44	2.98	4.60	
2	12.29	13.08	10.74	12.89	13.28	7.51	9.12	
3	12.27	13.03	10.46	12.77	13.45	9.91	10.19	
4	12.97	13.49	8.62	12.67	14.19	14.84	11.73	
5	13.49	14.31	10.92	11.79	14.70	20.50	15.71	
6	13.13	15.93	20.12	11.41	15.58	24.54	22.33	
7	12.92	17.78	26.49	11.69	17.23	28.29	27.39	
8	12.02	18.77	31.22	11.17	18.60	32.75	31.99	
9	10.86	17.93	31.96	10.25	18.67	34.87	33.42	
10	9.32	18.59	36.60	8.77	18.63	37.74	37.17	
11	7.68	18.13	38.86	6.69	18.15	40.69	39.78	

Run No. 72	PORT				STARBOARD			
POSITION	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
1	12.35	12.26	0.00	12.67	12.57	0.00	0.00	
2	11.46	11.99	8.74	11.89	11.95	3.04	5.89	
3	11.44	11.98	8.83	12.00	12.23	5.78	7.31	
4	12.20	12.25	2.78	12.03	12.99	11.80	7.29	
5	12.94	13.18	5.90	11.24	13.20	16.83	11.36	
6	12.69	14.62	16.71	10.89	14.08	21.49	19.10	
7	12.56	16.73	24.55	11.19	16.23	27.01	25.78	
8	11.23	19.56	34.69	10.37	19.10	35.52	35.10	
9	9.55	21.36	41.30	8.77	21.10	42.20	41.75	
10	7.37	21.23	44.75	6.67	21.46	46.24	45.49	
11	5.47	20.31	46.29	4.31	20.31	48.08	47.18	

TABLE 9 - UNDERWAY EXPERIMENTS, SPECIAL RUNS WITH DTNSRDC IMPELLER AND 5.75 IN. (0.146 m) NOZZLE

Run No. 74	POSITION	PORT			STARBOARD			AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
		STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC		
1		12.16	11.77	0.00	12.64	12.35	0.00	0.00	
2		11.58	11.71	4.29	11.77	11.67	0.00	2.15	
3		11.69	11.82	4.31	11.90	11.69	0.00	2.15	
4		12.14	11.99	0.00	11.81	12.44	9.52	4.76	
5		12.73	12.74	1.03	10.83	12.65	16.21	8.62	
6		12.52	13.97	14.49	10.65	13.38	19.85	17.17	
7		12.49	16.32	23.52	11.27	15.89	25.84	24.68	
8		11.09	19.54	34.95	10.18	18.84	35.37	35.16	
9		9.16	22.14	43.30	8.37	21.65	43.79	43.55	
10		6.56	22.61	48.16	5.90	22.71	49.28	48.72	
11		3.87	22.04	51.23	3.04	21.95	52.27	51.75	

Run No. 75	POSITION	PORT			STARBOARD			AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
		STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC		
1		12.10	11.67	0.00	12.74	12.38	0.00	0.00	
2		11.39	11.80	7.73	11.88	11.83	0.00	3.97	
3		11.81	11.91	3.76	12.01	12.04	2.03	2.89	
4		12.12	12.09	0.00	11.80	12.59	10.73	5.37	
5		12.65	12.82	5.06	10.95	12.66	15.74	10.40	
6		12.59	14.01	14.31	10.74	13.52	20.02	17.17	
7		12.37	16.31	23.86	11.18	15.74	25.68	24.77	
8		11.07	19.54	35.00	10.17	18.77	35.25	35.12	
9		9.01	22.35	43.91	8.33	21.73	44.01	43.96	
10		6.47	22.61	48.39	5.89	22.90	49.57	48.98	
11		3.56	21.48	50.89	3.20	21.80	51.84	51.36	

Run No. 76	PORT				STARBOARD				AVERAGE		NOZZLE	
POSITION	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	VELOCITY FT/SEC	VELOCITY FT/SEC	VELOCITY FT/SEC	VELOCITY FT/SEC	VELOCITY FT/SEC	VELOCITY FT/SEC
1	12.92	15.30	18.52	13.21	14.78	15.06	15.06	16.79	16.79	16.79	16.79	16.79
2	12.66	15.07	18.63	12.94	14.68	15.83	15.83	17.23	17.23	17.23	17.23	17.23
3	12.61	14.72	17.47	12.71	14.87	17.63	17.63	17.55	17.55	17.55	17.55	17.55
4	12.70	14.69	16.96	12.40	15.49	21.12	21.12	19.04	19.04	19.04	19.04	19.04
5	12.90	14.95	17.21	11.49	16.14	25.90	25.90	21.55	21.55	21.55	21.55	21.55
6	12.55	16.55	24.03	11.22	16.50	27.62	27.62	25.82	25.82	25.82	25.82	25.82
7	12.40	16.74	25.04	11.44	16.70	27.56	27.56	26.30	26.30	26.30	26.30	26.30
8	11.88	16.70	26.40	11.20	16.60	27.94	27.94	27.17	27.17	27.17	27.17	27.17
9	11.13	16.67	28.27	10.48	16.57	29.64	29.64	28.96	28.96	28.96	28.96	28.96
10	10.33	16.51	29.88	9.73	16.43	31.10	31.10	30.49	30.49	30.49	30.49	30.49
11	9.48	16.29	31.38	8.69	16.02	32.55	32.55	31.96	31.96	31.96	31.96	31.96

Run No. 77	PORT				STARBOARD				AVERAGE		NOZZLE	
POSITION	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	VELOCITY FT/SEC	VELOCITY FT/SEC	VELOCITY FT/SEC	VELOCITY FT/SEC	VELOCITY FT/SEC	VELOCITY FT/SEC
1	12.92	15.20	18.15	13.21	14.79	15.09	15.09	16.62	16.62	16.62	16.62	16.62
2	12.58	15.07	18.99	12.97	14.68	17.35	17.35	17.35	17.35	17.35	17.35	17.35
3	12.61	14.74	17.55	12.76	14.81	17.22	17.22	17.38	17.38	17.38	17.38	17.38
4	12.77	14.70	16.72	12.44	15.48	20.96	20.96	18.84	18.84	18.84	18.84	18.84
5	12.95	14.99	17.18	11.53	16.16	25.85	25.85	21.51	21.51	21.51	21.51	21.51
6	12.68	16.65	23.95	11.27	16.54	27.60	27.60	25.78	25.78	25.78	25.78	25.78
7	12.50	16.81	24.97	11.51	16.72	27.45	27.45	26.21	26.21	26.21	26.21	26.21
8	12.03	16.81	26.30	11.25	16.67	27.99	27.99	27.15	27.15	27.15	27.15	27.15
9	11.22	16.74	28.24	10.55	16.56	29.47	29.47	28.86	28.86	28.86	28.86	28.86
10	10.40	16.58	29.87	9.75	16.45	31.11	31.11	30.49	30.49	30.49	30.49	30.49
11	9.47	16.26	31.33	8.68	15.99	32.51	32.51	31.92	31.92	31.92	31.92	31.92

TABLE 10 - BOLLARD EXPERIMENTS WITH DTNSRDC IMPELLER AND 5.75 IN. (0.146 m) NOZZLE

Run No. 51

POSITION	PORT			STARBOARD			NOZZLE VELOCITY FT/SEC
	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	
1	13.12	14.48	14.01	13.03	14.20	12.97	13.49
2	12.67	14.47	15.24	12.86	14.31	14.48	14.86
3	12.73	13.94	13.20	12.71	14.31	15.18	14.19
4	12.77	14.50	16.09	12.45	14.27	16.22	16.15
5	12.76	14.61	16.35	11.95	14.21	18.09	17.22
6	12.64	14.43	16.09	11.76	14.25	18.97	17.53
7	12.45	14.66	17.87	11.63	14.40	20.04	18.95
8	12.10	14.49	18.60	11.63	13.70	17.31	17.96
9	11.83	13.40	15.02	11.54	12.26	10.20	12.61
10	11.48	12.04	9.00	11.03	11.42	7.49	8.25
11	11.75	11.91	4.92	11.58	11.48	0.00	2.46

Run No. 52

POSITION	PORT			STARBOARD			NOZZLE VELOCITY FT/SEC
	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	
1	12.69	14.45	15.95	12.71	14.21	14.70	15.32
2	12.36	14.44	17.33	12.47	14.30	16.26	16.80
3	12.18	14.05	16.46	12.31	14.27	16.82	16.64
4	12.28	14.42	17.58	11.97	14.25	18.16	17.87
5	12.23	14.57	18.40	11.29	14.19	20.46	19.43
6	12.06	14.34	18.12	11.01	14.24	21.60	19.86
7	11.84	14.58	19.89	10.91	14.35	22.29	21.09
8	11.39	14.45	21.04	10.89	13.58	19.73	20.38
9	10.52	13.47	20.64	10.46	11.77	13.79	17.21
10	10.66	11.41	10.40	10.24	10.64	7.60	9.00
11	10.90	11.05	4.64	10.77	10.65	0.00	2.32

Run No. 53	PORT				STARBOARD				AVERAGE	NOZZLE
POSITION	STATIC	TOTAL	VELOCITY	PRESSURE	STATIC	TOTAL	VELOCITY	PRESSURE	VELOCITY	VELOCITY
	PSIA	PSIA	FT/SEC	PSIA	PSIA	PSIA	FT/SEC	PSIA	FT/SEC	FT/SEC
1	12.28	14.42	17.57	12.38	14.20	16.23	16.90	14.20	16.90	
2	11.89	14.41	19.06	12.09	14.27	17.75	18.40	14.27	18.40	
3	11.71	13.94	17.94	11.87	14.29	18.70	18.32	14.29	18.32	
4	11.79	14.36	19.28	11.46	14.25	20.07	19.67	14.25	19.67	
5	11.73	14.56	20.22	10.66	14.18	22.56	21.39	14.18	21.39	
6	11.56	14.27	19.79	10.39	14.19	23.44	21.62	14.19	21.62	
7	11.28	14.57	21.80	10.30	14.36	24.22	23.01	14.36	23.01	
8	10.60	14.26	23.01	10.07	13.43	22.01	22.51	13.43	22.51	
9	9.86	13.04	21.44	9.48	11.12	15.43	18.44	11.12	18.44	
10	10.23	10.84	9.36	9.82	10.10	6.31	7.83	10.10	7.83	
11	10.18	10.34	4.81	10.04	9.98	0.00	2.41	9.98	2.41	

Run No. 54	PORT				STARBOARD				AVERAGE	NOZZLE
POSITION	STATIC	TOTAL	VELOCITY	PRESSURE	STATIC	TOTAL	VELOCITY	PRESSURE	VELOCITY	VELOCITY
	PSIA	PSIA	FT/SEC	PSIA	PSIA	PSIA	FT/SEC	PSIA	FT/SEC	FT/SEC
1	11.95	14.38	18.74	12.09	14.20	17.45	18.10	14.20	18.10	
2	11.50	14.33	20.20	11.70	14.27	19.26	19.73	14.27	19.73	
3	11.22	13.83	19.41	11.41	14.24	20.22	19.81	14.24	19.81	
4	11.30	14.43	21.27	10.92	14.17	21.66	21.47	14.17	21.47	
5	11.17	14.48	21.86	9.93	14.11	24.55	23.20	14.11	23.20	
6	11.07	14.19	21.23	9.52	14.19	25.97	23.60	14.19	23.60	
7	10.66	14.51	23.57	9.48	14.32	26.45	25.01	14.32	25.01	
8	9.93	14.46	25.59	9.35	13.05	23.11	24.35	13.05	24.35	
9	8.92	13.10	24.58	8.51	10.60	17.39	20.97	10.60	20.97	
10	9.65	10.17	8.67	9.17	9.21	2.22	5.44	9.21	5.44	
11	9.31	9.56	5.99	9.35	9.16	0.00	3.00	9.16	3.00	

Run No. 55

POSITION	STATIC PRESSURE PSIA	PORT TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	STARBOARD TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
1	11.61	14.36	19.96	11.72	14.15	18.74	19.35	
2	11.13	14.29	21.37	11.40	14.22	20.17	20.77	
3	10.86	13.74	20.39	11.01	14.22	21.56	20.97	
4	10.89	14.34	22.33	10.51	14.11	22.80	22.56	
5	10.79	14.48	23.07	9.41	14.07	25.93	24.50	
6	10.54	14.19	22.98	9.05	14.15	27.14	25.06	
7	10.13	14.41	24.87	8.91	14.27	27.81	26.34	
8	9.31	14.29	26.84	8.75	13.03	24.88	25.86	
9	8.28	12.72	25.33	7.91	10.26	18.40	21.86	
10	9.19	9.60	7.68	8.48	8.77	6.43	7.05	
11	8.74	9.01	6.22	8.83	8.54	0.00	3.11	

Run No. 56

POSITION	STATIC PRESSURE PSIA	PORT TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	STARBOARD TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
1	11.51	14.32	19.92	11.90	14.08	17.74	18.83	
2	11.06	14.26	21.47	11.43	14.22	20.08	20.78	
3	10.80	15.87	27.05	11.09	14.20	21.20	24.13	
4	10.92	14.39	22.39	10.54	14.18	22.92	22.65	
5	10.81	14.39	22.76	9.40	14.00	25.77	24.26	
6	10.63	14.29	23.00	9.02	14.19	27.33	25.17	
7	10.16	14.43	24.84	8.88	14.30	27.98	26.41	
8	9.28	14.33	27.02	8.61	13.00	25.20	26.11	
9	8.36	12.70	25.05	7.90	10.31	18.66	21.85	
10	9.15	9.65	8.49	8.50	8.85	7.10	7.80	
11	8.79	8.99	5.32	8.84	8.62	0.00	2.66	

COPY AVAILABLE TO DDC DOES NOT
PERMIT FULLY LEGIBLE PRODUCTION

TABLE 11 - UNDERWAY EXPERIMENTS WITH DTNSRDC IMPELLER AND 6.00 IN. (0.1524 m) NOZZLE

Run No. 90	POSITION	PORT			STARBOARD			AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
		STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC		
	1	14.00	15.06	12.37	14.01	14.60	9.22	10.79	
	2	13.88	14.93	12.33	13.85	14.56	10.15	11.24	
	3	13.86	14.77	11.44	13.79	14.67	11.26	11.35	
	4	13.91	14.81	11.35	13.69	14.70	12.10	11.73	
	5	14.02	15.01	11.93	13.37	15.21	16.31	14.12	
	6	13.98	15.67	15.66	13.22	15.50	18.14	16.90	
	7	13.89	15.92	17.11	13.28	15.67	18.58	17.84	
	8	13.67	15.90	17.95	13.26	15.69	18.77	18.36	
	9	13.33	15.91	19.30	13.00	15.57	19.29	19.29	
	10	12.80	16.02	21.55	12.37	15.74	22.05	21.80	
	11	12.50	15.80	21.82	12.07	15.50	22.28	22.05	

Run No. 91	POSITION	PORT			STARBOARD			AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
		STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC		
	1	13.86	14.92	12.37	13.99	14.57	9.22	10.80	
	2	13.79	14.77	11.89	13.85	14.60	10.44	11.17	
	3	13.74	14.62	11.28	13.80	14.62	10.84	11.06	
	4	13.79	14.64	11.10	13.69	14.85	12.93	12.01	
	5	13.91	14.85	11.66	13.38	15.16	16.04	13.85	
	6	13.87	15.53	15.46	13.22	15.45	17.95	16.71	
	7	13.81	15.80	16.98	13.34	15.61	18.11	17.55	
	8	13.59	15.78	17.80	13.29	15.67	18.55	18.18	
	9	13.24	15.76	19.06	13.02	15.51	18.95	19.01	
	10	12.76	15.81	21.18	12.42	15.67	21.68	21.43	
	11	12.47	15.68	21.54	12.12	15.47	22.02	21.78	

COPY AVAILABLE TO DDC DOES NOT
PERMIT FULLY LEGIBLE PRODUCTION

Run No. 92

POSITION	PORT STATIC PRESSURE PSIA	PORT TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STARBOARD STATIC PRESSURE PSIA	STARBOARD TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
1	13.72	15.15	14.38	13.82	14.72	11.41	12.90	
2	13.56	14.96	14.22	13.63	14.71	12.55	13.38	
3	13.51	14.78	13.50	13.56	14.80	13.38	13.44	
4	13.58	14.78	13.13	13.38	15.17	16.08	14.61	
5	13.70	15.01	13.75	12.91	15.51	19.37	16.56	
6	13.60	15.93	18.36	12.75	15.85	21.18	19.77	
7	13.48	16.15	19.61	12.85	16.01	21.38	20.49	
8	13.17	16.11	20.60	12.73	16.01	21.77	21.18	
9	12.62	16.24	22.86	12.21	16.02	23.46	23.16	
10	12.06	16.10	24.17	11.68	15.98	24.93	24.55	
11	11.63	15.84	24.67	11.11	15.78	25.97	25.32	

Run No. 93

POSITION	PORT STATIC PRESSURE PSIA	PORT TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STARBOARD STATIC PRESSURE PSIA	STARBOARD TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
1	13.60	15.03	14.41	13.83	14.71	11.27	12.84	
2	13.45	14.87	14.33	13.66	14.66	12.04	13.18	
3	13.46	14.66	13.17	13.56	14.80	13.40	13.29	
4	13.48	14.66	13.06	13.39	15.13	15.87	14.47	
5	13.62	14.86	13.42	12.91	15.55	19.52	16.47	
6	13.53	15.81	18.19	12.69	15.85	21.36	19.77	
7	13.40	16.16	19.99	12.87	16.01	21.32	20.66	
8	13.11	16.03	20.56	12.78	15.97	21.49	21.03	
9	12.59	16.10	22.50	12.20	16.01	23.47	22.98	
10	12.01	16.03	24.11	11.70	15.98	24.88	24.49	
11	11.59	15.78	24.61	11.16	15.77	25.81	25.21	

Run No. 94	PORT	STARBOARD	VELOCITY	VELOCITY	VELOCITY	NOZZLE
POSITION	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	FT/SEC	FT/SEC	FT/SEC	VELOCITY FT/SEC
1	13.60	15.22	15.30	13.67	14.90	14.32
2	13.37	15.05	15.57	13.46	14.84	14.85
3	13.35	14.81	14.50	13.35	14.94	14.81
4	13.42	14.80	14.09	13.13	15.36	16.02
5	13.51	15.05	14.89	12.52	15.85	18.42
6	13.39	16.15	19.97	12.32	16.17	21.78
7	13.20	16.33	21.27	12.47	16.29	22.40
8	12.85	16.27	22.22	12.30	16.26	23.06
9	12.24	16.32	24.30	11.64	16.29	25.11
10	11.66	16.23	25.71	11.18	16.13	26.23
11	11.06	15.92	26.49	10.44	15.85	27.22

Run No. 95	PORT	STARBOARD	VELOCITY	VELOCITY	VELOCITY	NOZZLE
POSITION	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	FT/SEC	FT/SEC	FT/SEC	VELOCITY FT/SEC
1	13.49	15.15	15.49	13.70	14.85	14.20
2	13.32	14.98	15.51	13.48	14.82	14.70
3	13.30	14.74	14.40	13.38	14.86	14.51
4	13.37	14.74	14.05	13.15	15.31	15.85
5	13.44	14.93	14.68	12.56	15.77	18.11
6	13.31	16.06	19.95	12.31	16.13	21.72
7	13.17	16.25	21.08	12.51	16.26	22.18
8	12.82	16.23	22.21	12.35	16.22	22.93
9	12.15	16.20	24.20	11.66	16.25	24.98
10	11.61	16.16	25.64	11.21	16.09	26.11
11	11.07	15.89	26.40	10.51	15.81	27.05

Run No. 96	PORT				STARBOARD				NOZZLE	
POSITION	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC		
1	13.34	15.27	16.71	13.40	14.84	14.42	15.57			
2	13.06	15.09	17.12	13.13	14.75	15.30	16.21			
3	13.06	14.82	15.96	13.03	14.85	16.23	16.09			
4	13.10	14.83	15.80	12.71	15.42	19.79	17.79			
5	13.17	15.06	16.51	12.03	15.90	23.63	20.07			
6	13.04	16.25	21.54	11.81	16.20	25.18	23.36			
7	12.85	16.44	22.78	11.98	16.33	25.07	23.93			
8	12.43	16.37	23.85	11.77	16.29	25.54	24.70			
9	11.64	16.39	26.19	10.98	16.34	27.83	27.01			
10	11.03	16.26	27.49	10.46	16.16	28.71	28.10			
11	10.33	15.91	28.39	9.64	15.76	29.73	29.06			

Run No. 97	PORT				STARBOARD				NOZZLE	
POSITION	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC		
1	13.22	15.18	16.81	13.42	14.85	14.38	15.59			
2	12.98	15.02	17.18	13.19	14.75	15.03	16.10			
3	12.96	14.76	16.12	13.06	14.92	16.41	16.26			
4	13.00	14.69	15.60	12.79	15.36	19.24	17.42			
5	13.11	14.94	16.28	12.03	15.93	23.75	20.01			
6	12.95	16.25	21.84	11.83	16.26	25.29	23.56			
7	12.78	16.40	22.88	12.03	16.42	25.21	24.04			
8	12.39	16.35	23.92	11.80	16.35	25.66	24.79			
9	11.61	16.40	26.29	11.00	16.43	27.99	27.14			
10	10.97	16.25	27.62	10.51	16.21	28.71	28.17			
11	10.35	15.95	28.46	9.68	15.83	29.81	29.14			

COPY AVAILABLE TO DDC DOES NOT
PERMIT FULLY LEGIBLE PRODUCTION

Run No. 98

POSITION	PORT			STARBOARD			AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC		
1	13.18	15.35	17.70	13.34	14.87	14.84	16.27	
2	12.92	15.16	17.98	13.06	14.78	15.75	16.87	
3	12.92	14.88	16.81	12.88	14.97	17.40	17.11	
4	12.94	14.85	16.63	12.50	15.60	21.15	18.89	
5	13.06	15.15	17.35	11.67	16.10	25.32	21.34	
6	12.84	16.55	23.17	11.44	16.51	27.05	25.11	
7	12.66	16.64	23.98	11.69	16.61	26.66	25.32	
8	12.13	16.56	25.32	11.37	16.51	27.25	26.28	
9	11.29	16.54	27.54	10.67	16.45	28.92	28.23	
10	10.61	16.44	29.02	9.97	16.37	30.42	29.72	
11	9.81	16.06	30.05	9.08	16.00	31.62	30.84	

Run No. 99

POSITION	PORT			STARBOARD			AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC		
1	13.12	14.24	12.70	13.49	13.93	7.95	10.33	
2	12.56	14.01	14.46	13.11	13.95	11.02	12.74	
3	12.66	13.89	13.32	12.96	14.27	13.77	13.55	
4	12.93	14.15	13.28	12.70	14.88	17.78	15.53	
5	13.29	14.88	15.16	11.77	15.51	23.24	19.20	
6	12.97	16.45	22.42	11.45	16.41	26.77	24.59	
7	12.75	17.50	26.20	11.72	17.36	28.56	27.38	
8	12.08	17.76	28.64	11.39	17.62	30.01	29.33	
9	11.09	17.61	30.69	10.55	17.53	31.75	31.22	
10	9.87	17.62	33.47	9.41	17.56	34.33	33.90	
11	8.71	16.96	34.53	7.99	16.95	35.98	35.25	

COPY AVAILABLE TO DDC DOES NOT
PERMIT FULLY LEGIBLE PRODUCTION

Run No. 100

POSITION	STATIC PRESSURE PSIA	PORT TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	STARBOARD TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
1	13.08	14.59	14.76	13.39	13.75	7.14	10.95	
2	12.45	13.68	13.29	12.99	13.79	10.73	12.01	
3	12.60	13.66	12.38	12.83	14.07	13.34	12.86	
4	13.00	13.83	10.92	12.54	14.67	17.55	14.23	
5	13.32	14.65	13.86	11.58	15.29	23.17	18.51	
6	12.97	16.25	21.77	11.14	16.19	27.00	24.39	
7	12.69	17.70	26.91	11.42	17.47	29.56	28.23	
8	11.97	18.10	29.74	11.05	18.06	31.81	30.77	
9	10.95	17.94	31.79	10.29	17.99	33.36	32.58	
10	9.55	17.97	34.87	8.94	17.93	36.05	35.46	
11	8.29	17.16	35.80	7.39	17.25	37.75	36.77	

Run No. 101

POSITION	STATIC PRESSURE PSIA	PORT TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	STARBOARD TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
1	12.92	13.90	11.88	13.35	13.81	8.19	10.03	
2	12.46	13.76	13.72	13.00	13.89	11.36	12.54	
3	12.59	13.70	12.66	12.86	14.12	13.46	13.06	
4	12.89	13.95	12.37	12.59	14.73	17.57	14.97	
5	13.23	14.48	13.43	11.56	15.36	23.43	18.43	
6	12.85	16.27	22.23	11.18	16.33	27.30	24.76	
7	12.67	17.56	26.58	11.48	17.49	29.46	28.02	
8	11.93	18.04	29.72	11.22	18.01	31.32	30.52	
9	10.90	17.89	31.78	10.32	17.90	33.09	32.44	
10	9.59	17.88	34.63	9.04	17.96	35.90	35.27	
11	8.28	17.34	36.18	7.47	17.27	37.62	36.90	

Run No. 102		PORT				STARBOARD			
POSITION	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC	
1	12.83	12.91	3.50	13.32	12.88	0.00	1.75		
2	12.22	12.81	9.25	12.80	12.79	0.00	4.62		
3	12.35	12.82	8.27	12.75	13.07	6.73	7.50		
4	12.86	13.08	5.68	12.44	13.86	14.31	10.00		
5	13.27	13.95	9.92	11.56	14.36	20.11	15.02		
6	12.99	15.73	19.88	11.01	15.37	25.09	22.48		
7	12.00	17.61	26.74	11.39	17.16	28.88	27.81		
8	11.73	18.56	31.42	10.85	18.40	33.02	32.22		
9	10.58	18.51	33.86	9.84	18.41	35.19	34.53		
10	8.95	15.38	30.48	8.33	18.42	38.19	34.33		
11	7.43	17.63	38.39	6.40	17.57	40.17	39.28		

Run No. 103		PORT				STARBOARD			
POSITION	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC	
1	12.86	13.17	6.71	13.34	13.04	0.00	3.36		
2	12.25	12.88	9.58	12.81	12.84	2.08	5.83		
3	12.32	12.85	8.80	12.72	13.13	7.71	8.25		
4	12.74	13.15	7.73	12.47	13.97	14.76	11.25		
5	13.28	13.94	9.74	11.54	14.45	20.52	15.13		
6	12.89	15.75	20.32	11.01	15.54	25.59	22.96		
7	12.67	17.54	26.54	11.37	17.29	29.27	27.90		
8	11.76	18.44	31.05	10.94	18.23	32.46	31.76		
9	10.61	18.43	33.61	9.99	18.27	34.59	34.10		
10	8.91	18.29	36.81	8.36	18.29	37.87	37.34		
11	7.40	17.53	38.29	6.46	17.51	39.95	39.12		

Run No. 104		PORT				STARBOARD			
POSITION	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC	
1	12.04	12.27	5.80	12.47	12.43	0.00	2.90		
2	11.24	12.05	10.84	11.81	12.05	5.85	8.35		
3	11.14	11.93	10.71	11.70	12.27	9.06	9.88		
4	11.98	12.29	6.70	11.73	13.07	13.92	10.31		
5	12.77	13.25	8.28	10.90	13.38	18.92	13.60		
6	12.50	14.95	18.81	10.45	14.23	23.36	21.09		
7	12.18	17.11	26.69	10.85	16.72	29.12	27.90		
8	10.94	19.82	35.82	10.02	19.57	37.14	36.48		
9	9.16	21.23	41.76	8.37	21.28	43.19	42.47		
10	6.86	21.16	45.46	6.31	21.43	46.75	46.11		
11	4.65	20.34	47.61	3.56	20.35	49.26	48.44		

Run No. 105		PORT				STARBOARD			
POSITION	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC	
1	11.91	12.01	3.79	12.30	12.20	0.00	1.90		
2	11.15	11.98	10.94	11.74	12.03	6.41	8.68		
3	11.09	11.92	10.94	11.87	12.34	6.24	9.59		
4	12.00	12.33	6.92	11.86	13.18	13.84	10.38		
5	12.79	13.52	10.24	10.94	13.57	19.48	14.86		
6	12.44	15.03	19.36	10.67	14.49	23.48	21.42		
7	12.28	17.42	27.25	10.95	16.79	29.04	28.15		
8	10.98	19.95	35.99	10.15	19.66	37.07	36.53		
9	9.35	20.83	40.73	8.62	20.98	42.26	41.49		
10	7.03	20.94	44.82	6.48	21.12	46.00	45.41		
11	4.66	20.15	47.32	3.76	20.30	48.88	48.10		

COPY AVAILABLE TO DDC DOES NOT
PERMIT FULLY LEGIBLE PRODUCTION

Run No. 106

POSITION	PORT		STARBOARD		NOZZLE VELOCITY FT/SEC
	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	
1	11.72	11.57	12.13	11.79	0.00
2	10.61	11.37	11.57	11.38	4.49
3	10.72	11.23	11.32	11.31	4.30
4	11.73	11.70	11.38	12.11	5.13
5	12.32	12.57	10.47	12.28	11.11
6	12.02	14.00	10.13	13.15	18.89
7	12.06	16.66	10.69	15.79	26.48
8	10.48	19.87	9.70	19.13	36.87
9	8.29	22.66	7.62	22.17	45.71
10	5.61	22.90	5.07	23.10	50.51
11	2.50	21.92	1.72	21.81	53.43

Run No. 107

POSITION	PORT		STARBOARD		NOZZLE VELOCITY FT/SEC
	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	
1	11.60	11.46	12.16	11.87	0.00
2	10.70	11.35	11.49	11.50	5.53
3	10.61	11.22	11.36	11.39	5.61
4	11.75	11.75	11.29	12.18	5.66
5	12.29	12.66	10.39	12.40	12.15
6	12.08	14.16	10.05	13.37	19.62
7	12.04	16.67	10.64	15.93	26.76
8	10.55	20.05	9.75	19.21	37.02
9	8.39	22.51	7.80	22.16	45.36
10	5.68	22.91	5.22	22.91	50.23
11	2.62	21.77	1.81	21.82	53.19

COPY AVAILABLE TO DDC DOES NOT
PERMIT FULLY LEGIBLE PRODUCTION

TABLE 12 - UNDERWAY EXPERIMENTS, SPECIAL RUNS WITH DTNSRDC IMPELLER AND 6.00 IN. (0.1524 m) NOZZLE

Run No. 108

POSITION	PORT			STARBOARD			NOZZLE VELOCITY FT/SEC
	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	
1	12.75	14.84	17.41	13.14	14.23	12.56	14.98
2	12.20	14.55	18.45	12.82	14.25	14.36	16.41
3	12.33	14.14	16.16	12.55	14.52	16.89	16.53
4	12.56	14.29	15.85	12.22	15.26	20.94	18.40
5	12.88	14.96	17.33	11.14	16.07	26.68	22.01
6	12.49	16.89	25.21	10.75	16.95	29.93	27.57
7	12.30	17.66	27.84	11.05	17.61	30.78	29.31
8	11.61	17.73	29.75	10.71	17.64	31.63	30.69
9	10.62	17.53	31.61	9.93	17.45	32.96	32.28
10	9.28	17.42	34.30	8.65	17.37	35.50	34.90
11	8.08	16.82	35.53	7.20	16.79	37.22	36.37

Run No. 109

POSITION	PORT			STARBOARD			NOZZLE VELOCITY FT/SEC
	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	
1	12.75	14.67	16.67	13.12	14.16	12.26	14.47
2	12.27	14.60	18.37	12.77	14.25	14.56	16.52
3	12.23	14.13	16.54	12.69	14.44	15.91	16.22
4	12.53	14.31	16.05	12.23	15.40	21.40	18.72
5	12.79	15.01	17.92	11.19	16.11	26.67	22.29
6	12.43	17.03	25.77	10.80	16.92	29.74	27.75
7	12.22	17.60	27.88	11.08	17.46	30.38	29.13
8	11.64	17.63	29.41	10.79	17.59	31.34	30.38
9	10.65	17.44	31.32	10.01	17.38	32.64	31.98
10	9.34	17.28	33.87	8.74	17.24	35.04	34.45
11	8.12	16.63	35.17	7.35	16.71	36.79	35.98

TABLE 13 - BOLLARD EXPERIMENTS WITH DTNSRDC IMPELLER AND 6.00 IN. (0.1524 m) NOZZLE

Run No. 80	PORT				STARBOARD			
	POSITION	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC
	1	13.30	14.38	12.50	13.23	14.29	12.36	12.43
	2	13.16	14.38	13.26	13.09	14.44	13.95	13.61
	3	12.76	14.12	14.01	13.02	14.42	14.23	14.12
	4	12.90	14.48	15.13	12.69	14.41	15.77	15.45
	5	12.86	14.54	15.57	12.26	14.42	17.68	16.63
	6	12.76	14.50	15.84	12.11	14.45	18.36	17.10
	7	12.64	14.57	16.72	12.05	14.52	18.92	17.82
	8	12.41	14.48	17.28	12.09	14.03	16.75	17.02
	9	12.33	13.55	13.23	12.05	12.85	10.75	11.99
	10	12.17	12.62	8.32	11.92	12.20	6.43	7.37
	11	11.96	12.38	7.77	12.15	12.15	.29	4.03

Run No. 81	PORT				STARBOARD			
	POSITION	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC
	1	12.63	14.35	15.78	12.75	14.35	15.19	15.49
	2	12.34	14.37	17.12	12.48	14.43	16.82	16.97
	3	12.13	14.00	16.44	12.35	14.42	17.31	16.88
	4	12.20	14.42	17.93	12.01	14.40	18.56	18.25
	5	12.17	14.42	18.01	11.40	14.37	20.74	19.37
	6	12.04	14.37	18.32	11.21	14.41	21.52	19.92
	7	11.76	14.57	20.13	11.08	14.53	22.32	21.22
	8	11.39	14.50	21.17	11.11	13.94	20.20	20.69
	9	11.08	13.45	18.49	10.92	12.04	12.70	15.60
	10	10.71	11.80	12.56	10.42	11.12	10.09	11.33
	11	10.97	11.47	8.48	11.10	11.14	2.56	5.52

Run No. 82

POSITION	PORT			STARBOARD			NOZZLE VELOCITY FT/SEC
	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	
1	12.11	14.30	17.78	12.40	14.27	16.44	17.11
2	11.79	14.33	19.15	12.09	14.40	18.26	18.70
3	11.46	13.88	18.69	11.88	14.40	19.10	18.89
4	11.60	14.35	19.93	11.48	14.36	20.39	20.16
5	11.55	14.43	20.42	10.71	14.29	22.74	21.58
6	11.38	14.33	20.65	10.45	14.35	23.76	22.21
7	11.08	14.48	22.16	10.33	14.46	24.45	23.30
8	10.59	14.39	23.44	10.30	13.65	22.02	22.73
9	9.78	13.23	22.32	9.80	11.38	15.10	18.71
10	10.08	11.03	11.73	9.97	10.34	7.32	9.53
11	10.12	10.60	8.33	10.31	10.26	0.00	4.17

Run No. 83

POSITION	PORT			STARBOARD			NOZZLE VELOCITY FT/SEC
	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	
1	11.62	14.18	19.24	12.08	14.24	17.67	18.46
2	11.31	14.30	20.78	11.73	14.37	19.50	20.14
3	10.92	14.32	22.17	11.48	14.39	20.51	21.34
4	11.02	14.30	21.95	11.02	14.33	21.87	21.91
5	10.95	14.42	22.40	10.10	14.27	24.56	23.48
6	10.79	14.33	22.63	9.77	14.29	25.56	24.10
7	10.47	14.47	24.02	9.66	14.44	26.27	25.14
8	9.70	14.37	25.95	9.48	13.52	24.15	25.05
9	9.00	12.98	23.97	8.71	10.80	17.39	20.68
10	9.40	10.38	11.57	9.27	9.68	7.64	9.60
11	9.25	9.89	9.60	9.59	9.56	0.00	4.80

COPY AVAILABLE TO DDC DOES NOT
PERMIT FULLY LEGIBLE PRODUCTION

Run No. 84	PORT				STARBOARD			
POSITION	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
1	11.21	14.22	20.88	11.80	14.17	18.50	19.69	
2	10.84	14.17	21.95	11.28	14.33	20.98	21.46	
3	10.38	13.52	21.29	11.00	14.34	21.97	21.63	
4	10.49	14.26	23.37	10.49	14.28	23.38	23.37	
5	10.39	14.35	23.91	9.38	14.26	26.55	25.23	
6	10.24	14.16	23.83	9.10	14.30	27.42	25.62	
7	9.89	14.35	25.36	8.97	14.45	28.13	26.75	
8	8.74	14.42	28.65	8.64	13.44	26.33	27.49	
9	8.20	12.45	24.80	7.92	10.42	19.02	21.91	
10	8.81	9.46	9.74	8.44	8.86	7.80	8.77	
11	8.39	9.06	9.85	8.79	8.72	0.00	4.92	

Run No. 85	PORT				STARBOARD			
POSITION	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
1	10.91	14.27	22.04	11.43	14.21	20.04	21.04	
2	10.43	14.23	23.43	10.99	14.38	22.11	22.77	
3	9.89	13.55	23.03	10.62	14.39	23.34	23.18	
4	9.98	14.25	24.85	9.97	14.30	25.02	24.93	
5	9.91	14.37	25.38	8.69	14.21	28.24	26.81	
6	9.80	14.21	25.24	8.36	14.29	29.27	27.26	
7	9.27	14.42	27.30	8.23	14.50	30.10	28.70	
8	7.99	14.51	30.69	7.72	13.41	28.66	29.68	
9	7.84	11.91	24.25	7.58	9.81	17.96	21.11	
10	9.15	8.90	10.43	7.73	8.28	8.91	9.67	
11	7.57	8.38	10.83	7.89	8.07	5.10	7.96	

**COPY AVAILABLE TO DDC DOES NOT
PERMIT FULLY LEGIBLE PRODUCTION**

Run No. 86

POSITION	PORT		STARBOARD		VELOCITY FT/SEC	AVERAGE VELOCITY FT/SEC	NOZZLE VELOCITY FT/SEC
	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA	STATIC PRESSURE PSIA	TOTAL PRESSURE PSIA			
1	10.69	14.21	11.16	14.07	20.50	21.51	
2	10.21	14.19	10.77	14.39	22.86	23.41	
3	9.83	13.53	10.38	14.37	23.99	23.55	
4	9.76	14.23	9.64	14.28	25.88	25.64	
5	9.70	14.33	8.34	14.17	29.02	27.45	
6	9.47	14.10	7.99	14.27	30.12	27.99	
7	8.85	14.39	7.81	14.38	30.80	29.56	
8	7.41	14.54	7.48	13.27	28.94	30.51	
9	7.59	11.49	7.32	9.85	19.14	21.44	
10	7.80	8.59	7.30	7.93	9.51	10.09	
11	7.24	8.06	7.55	7.73	5.04	7.98	

DTNSRDC ISSUES THREE TYPES OF REPORTS

(1) DTNSRDC REPORTS, A FORMAL SERIES PUBLISHING INFORMATION OF PERMANENT TECHNICAL VALUE, DESIGNATED BY A SERIAL REPORT NUMBER

(2) DEPARTMENTAL REPORTS, A SEMIFORMAL SERIES, RECORDING INFORMATION OF A PRELIMINARY OR TEMPORARY NATURE, OR OF LIMITED INTEREST OR SIGNIFICANCE, CARRYING A DEPARTMENTAL ALPHANUMERIC IDENTIFICATION

(3) TECHNICAL MEMORANDA, AN INFORMAL SERIES, USUALLY INTERNAL WORKING PAPERS OR DIRECT REPORTS TO SPONSORS, NUMBERED AS TM SERIES REPORTS, NOT FOR GENERAL DISTRIBUTION.